July 1969

FINAL REPORT

LEM MISSION SIMULATOR

FILM GRAPHICS

CONTRACT NAS 9-5981

Aero Service Corporation

4219 Van Kirk Street

Philadelphia, Pennsylvania 19135

A Division of Litton Industries

Prepared for:

National Aeronautics and Space Administration

Manned Spacecraft Center

2101 Webster-Seabrook Road

Houston, Texas 77058

TABLE OF CONTENTS

Page

FIGURES AND TABLES

	Tables	
Land Use Categories	1	10
Land Use Color Mixes	11	11

Compilation of Master Data Base

Original Source Data. The primary considerations in the selection of source material for the master data base were:

1. Map scale
2. The amount of detail shown
3. The projection upon which the map was compiled

The first phase of the program entailed a judicious selection of charts and other source material which took the above factors into consideration. After all available charts and maps had been evaluated, it was decided that the Global Navigation Chart -- at a scale of 1:5,000,000 -- was the optimum chart in terms of detail and scale. (See Figure 1 Pages 2 thru 4) However, for the production of the film graphics, the chart presented a problem in terms of projection. The GNC'S are compiled on the Lambert Conic Conformal Projection. Being a conic conformal projection, the meridians converge quite rapidly at the higher latitudes, where the Cylindrical Equal Space Projection (required by the specifications), does not depict the meridians as converging. Because of the dissimilarity between the two projections, much detailed paneling was required.

WAC'S USED FOR LANDMARKS

Seq.	WAC	Edition	Litho Date
04	769	12th	11-60
07	526	7th Rev.	10-60
10	647	11th	9-62
17	829	10th	4-61
21	526	7th Rev.	10-60
28	526	7th Rev.	10-60
30	585	7th	1-62
31	585	7th	1-62
38	707	6th Rev.	3-60
40	648	9th	7-62
52	649	9th	10-62
53	771	8th Rev.	4-61
56	649	8th	5-59
58	772	7th Rev.	4-61
60	826	5th	10-60
65	825	8th	3-60
70	945	4th Rev.	1-52
77	944	4th	4-52
81	1018	6th	10-59
85	697	8th	7-58
86	575	9th	1-62
88	697	8th	7-58
94	780	6th	6-60
97	815	5th	6-56
98	937	6th	1-60
99	815	5th	6-56
101	936	6th	1-60
103	1027	3rd	6-51
108	1027	3rd	6-51
110	1422	5th	2-60
113	1421	4th Rev.	2-52
114	1055	5th	11-60
116	1054	5th	11-60
117	1176	5th	11-60
120	1030	5th	12-54
122	1398	4th	9-51
124	689	9th Rev.	5-60
126	932	7th Rev.	7-61
129	1175	6th	1-53
130	1154	4th Rev.	11-51

Figure 1

Seq.	WAC	Edition	Litho Date
131	1276	6th	11-60
135	910	4th	6-57
136	789	4th	2-56
137	810	4th Rev.	5-52
138	1031	5th	8-57
142	1297	5th	11-60
143	1052	3rd Rev.	2-52
144	1156	5th	2-52
146	791	2nd Rev.	3-51
148	920	6	1-51
149	859		
158	.739	7th	2-51
162	1346	6th	9-51
165	1102	6th	1-62
169	1229	7th	1-62
170	1461	6th	12-60
183	742	9th	1-59
187	1460	4th	11-52
188	1100	5th	12-61
190	863	9th	11-60
192	855	7th Rev.	7-52
194	976	7th	11-60
198	1109	9th	11-60
204	854	4th Rev.	5-49
205	1458	6th	9-52
206	975	7th	2-52
207	1110	6th	10-59
211	1458	6th	9-52
217	731	8th	10-52
218	1219	7th	1-62
219	988	7th Rev.	6-58
222	1235	6th	6-52
224	1456	8th	8-53
227	1340	11th	12-61
229	1340	11th	12-61
232	990	6th	6-56
234	599	11th	6-57
235	599	11th	6-57
236	1094	8th	2-52
237	1115	5th	12-51
238	1238	5th	2-52
311	590	9th	10-62
312	590	9th	10-62

Figure 1 (cont'd)

Ser.	WAC	Edition	Litho Date
315	589	9th	11-60
317	468	32nd	12-62
320	710	5th	9-62
321	587	8th	6-60
322	710	5th	9-62

GNC'S	Base Info. Compiled		Revision	
2	September	1957	April	1965
4	September	1957	June	1964
5	September	1957	May	1960
6	January	1959	August	1961
7	September	1957	August	1962
8	September	1957	December	1964
9	September	1957	December	1961
10	September	1957	August	1962
11	September	1957	April	1964
12	September	1957	August	1964
13	April	1965	September	1965
14	March	1958	April	1965
15	March	1958	December	1964
16	March	1958	December	1965
17	March	1958	September	1963
18	March	1958	April	1963
19	March	1958	May	1962
20	March	1958	March	1965
21	March	1958	May	1961
22	March	1959	May	1961
23	April	1964		
24	March	1964	July	1965
25	March	1958	August	1961

Figure 1 (cont'd)

Paneling of Original Source Data. As mentioned in the previous section, the Global Navigation Charts are compiled on a Lambert Conic Conformal Projection; therefore, the paneling operation was essentially one of projection conversion, whereby Aero Service Corporation converted the conic projection to a cylindrical projection. In terms of time and accuracy, the GNC'S were originally paneled to an intermediate cylindrical equal space projection. In order to overcome the problem of convergence on the conic projection, each five degree band of latitude was individually paneled to an intermediate cylindrical projection grid. (See Figure 2 Page 6) The end product of this paneling operation was a series of individual map strips which were rectified to conform to the Cylindrical Equal Space Projection. Since each five degree band was compiled at a slightly different scale, the next step in the sequence of operations was a photographic reduction of each band to the final common compilation scale.

In the final phase of the paneling operation, the photo negatives of the five degree bands were assembled on a transparent overlay of stable base .007" Mylar, punch registered to a scribed master projection. After completion of the entire master panel, a complete edit and inspection was performed

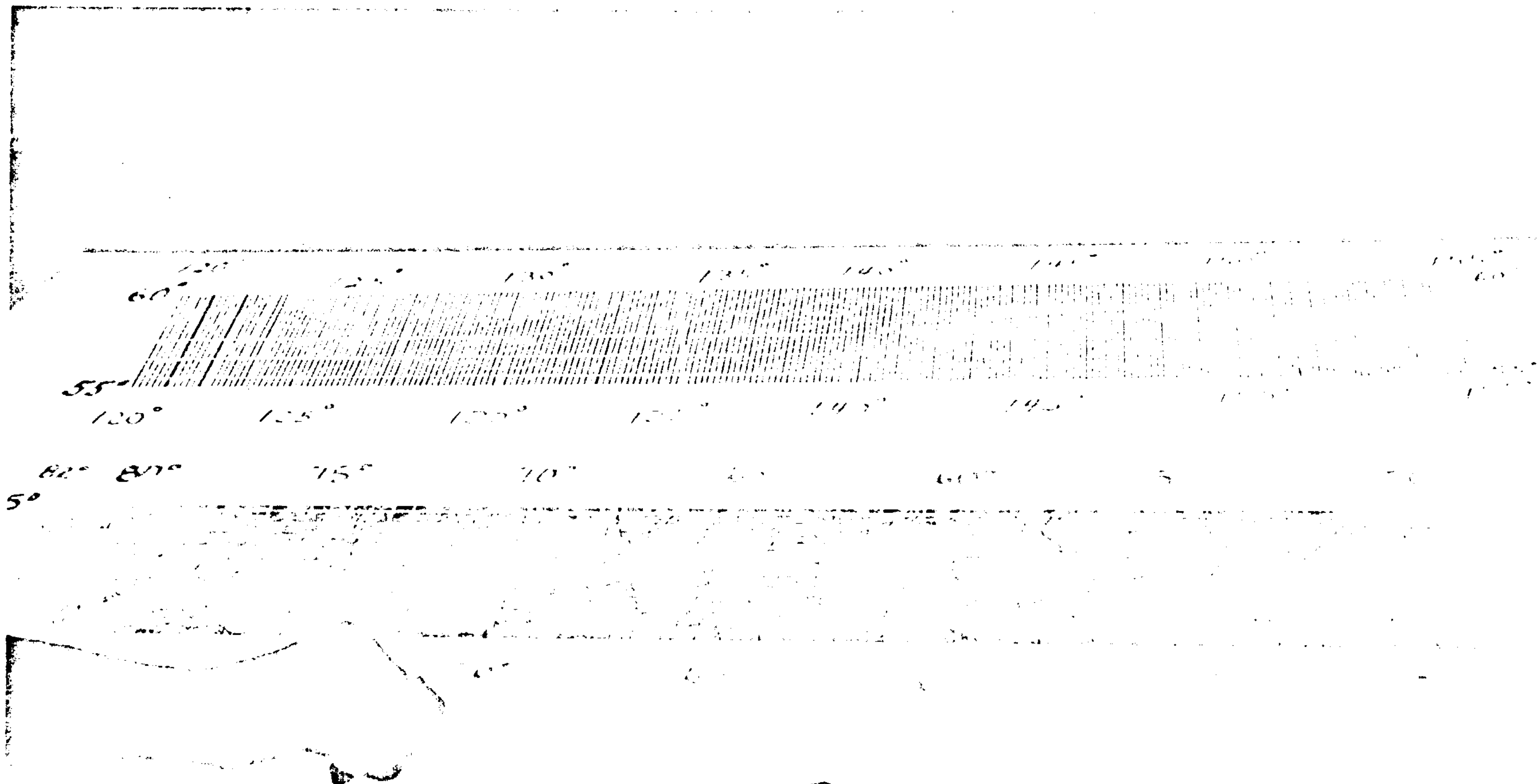


FIGURE 2 (Top to bottom) Scribed projection, paneled band from 55° north to 60° north and paneled band 0° to 5° north. The light vertical lines in the paneled strips are the cuts that were required to convert the conic projection to a Cylindrical Equal Space Projection. Due to the convergence toward the poles in the conic projection, more cuts were required to convert the 55-60 degree band than were required in the 0-5 degree band.

by the Aero Service Quality Assurance Group. A contact positive was then photographically printed from the master panel.

Construction of Projection Grids. All projection grids, both intermediate and final, were accurately scribed on K & E .0075" Stabilene Scribecote which has a Mylar base with a high degree of stability. The projection plotting was performed with a Haag-Streit Coordinatograph that has a plotting accuracy of ± .0015". The intermediate grid projection was scribed at one degree intervals which insured the specified positional accuracy.

The basic design philosophy for the terrestrial graphics was based on producing a single master manuscript. Therefore, a single master Cylindrical Equal Space Projection was constructed at a scale of 160 nautical miles to the inch. The overall size of the master grid, scribed every ten degrees, is 45.0" by 138.75" and encompasses 370 degrees of longitude (10 degree duplication) and 120 degrees of latitude ranging from 60 degrees north to 60 degrees south.

The terrestrial scene started at 33 degrees West Longitude and terminated at 23 degrees West Longitude with the entire overlap area falling in the Atlantic Ocean.

Rendering of Master Artwork. It was decided that rendering the terrestrial manuscript in color would afford a high degree of realism in addition to depicting the required fidelity in terms of texture and pattern definition. The various tints and shades were rigorously tested to insure color consistency and stability and were proven acceptable for both color and monochromatic response. (See Figure 3 Page 9)

Land use keys and corresponding color mixes which were developed for the Apollo Earth Sphere were used in the color rendering. The color schedule was established by categorizing various types of terrain and cultivated areas. These are listed in Table I, Page 10.

Topographic Detail. Mountainous terrain areas were rendered so as to provide an illusion of relief. This was accomplished by color shading techniques. (See Table II, Page 11)

Agricultural and vegetation patterns were simulated by over-painting color tones and textures. Reference material, to insure the most realistic portrayal, consisted of available orbital photography and the large collection of aerial

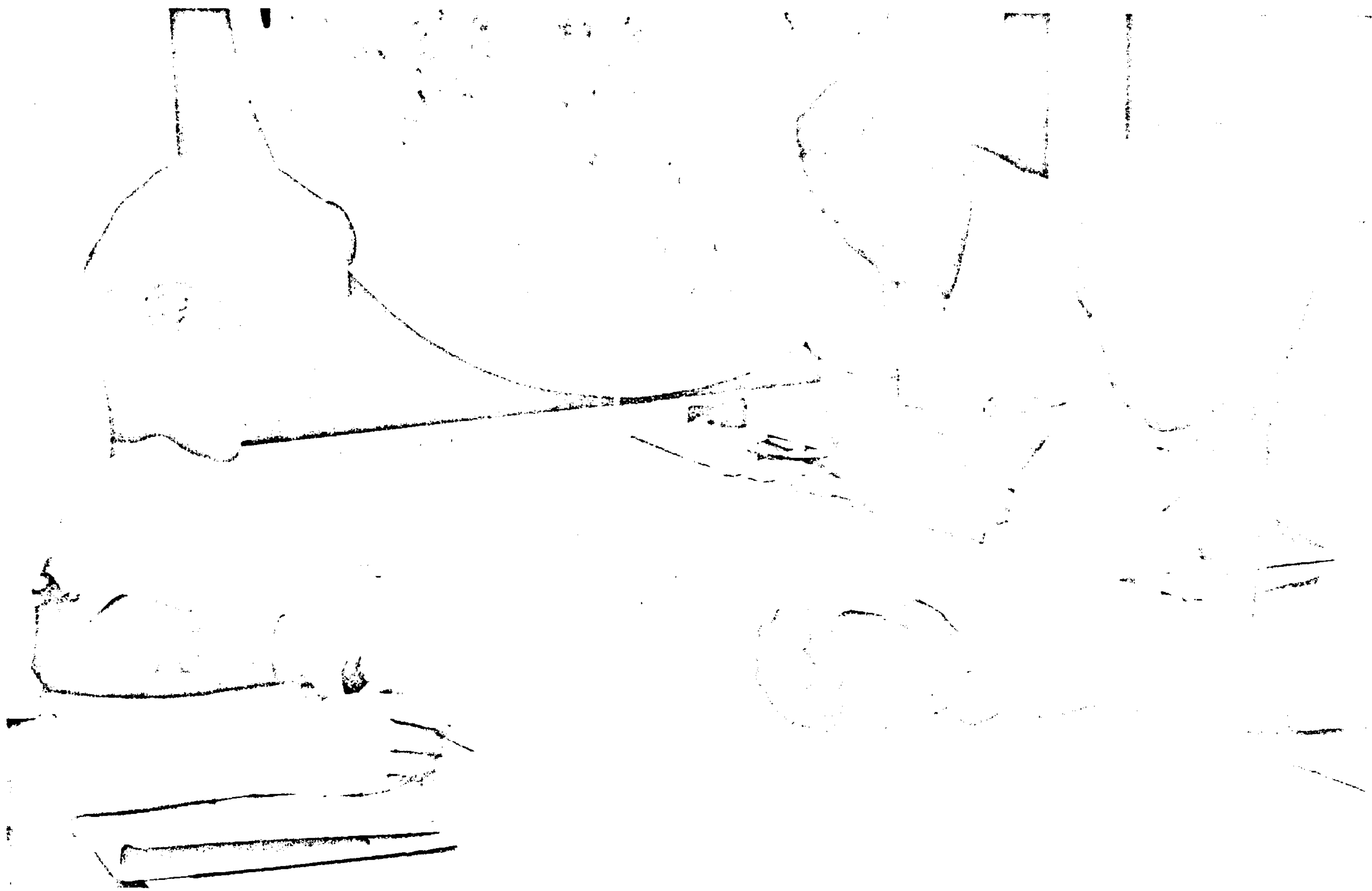


FIGURE 3 Aero technicians editing the final terrestrial manuscript. During this phase, the manuscript was checked for detail, positional accuracy, and tonal rendering.

Land Use Keys

TABLE I

1) Cultivated areas

   a. Fine texture

   b. Coarse texture

2) Intermixed forest and cropland

3) Forest

4) Intermixed forest and grassland

5) Scrub, bush, steppe, and grassland

6) Desert

   a. Fine texture

   b. Coarse texture

7) Irrigated areas

8) Oases

9) Tundra

10) Snow and ice

11) Mountain areas

12) Marsh or swamp

   a. Forested

   b. Grass

Colors Used in Portraying Major Topographic Features

TABLE II

Ocean water areas	Strong blue
Broad rivers	Dark blue green
Fresh water lakes	Dark blue green
Densely wooded areas	Dark green
Partial tree cover	Green
Semi-arid brushland	Light green
Tundra	Light green
Grassland	Light green
Agricultural areas	Light green
Rocky desert	Brown
Rocky areas	Brown
Glaciers	White with blue cast
Major urban areas	Mottled light gray

photography in Aero's film library.

Rendering of detail such as rivers, peninsulas, and other various land and water forms conform with the specification; that is, minimum detail of three nautical miles or more was portrayed.

Photographic Copying of Master Artwork

Artwork and Camera Alignment. The master artwork was mounted on an open faced vacuum easel measuring 72 inches high by 146 inches long. (See Figure 4, Page 13) The artwork was accurately positioned on the easel by means of a pin registration system which was designed specifically for this project. An equatorial reference grid permitted accurate alignment of the Robertson Tri-Color Camera film holder which has been designed to permit both vertical and horizontal adjustment. When accurately positioned, the artwork and camera film holder remained fixed throughout the entire copy sequence.

Continuous Film Strip Exposure Technique. As previously stated, the master artwork actually covers 370 degrees; that is, one complete orbit plus ten degrees of overlap. By using a specially designed fade-in, fade-out device, the duplicated area received one half of the exposure on the fade-out and

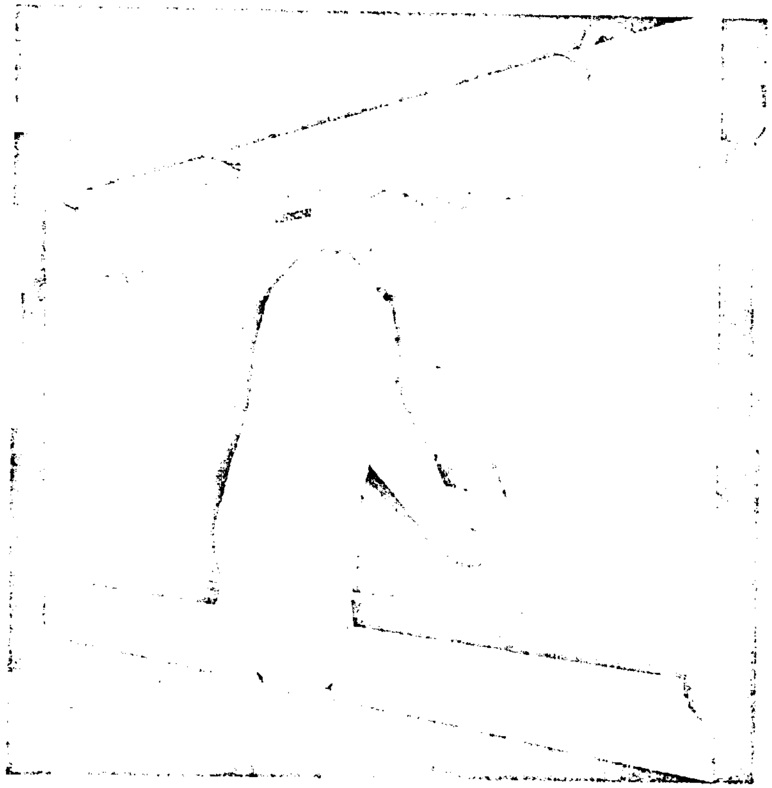


FIGURE 4 Photo Lab technician aligning terrestrial master artwork on open face vacuum easel. The easel, measuring 146 inches by 72 inches, is mounted on an overhead track.

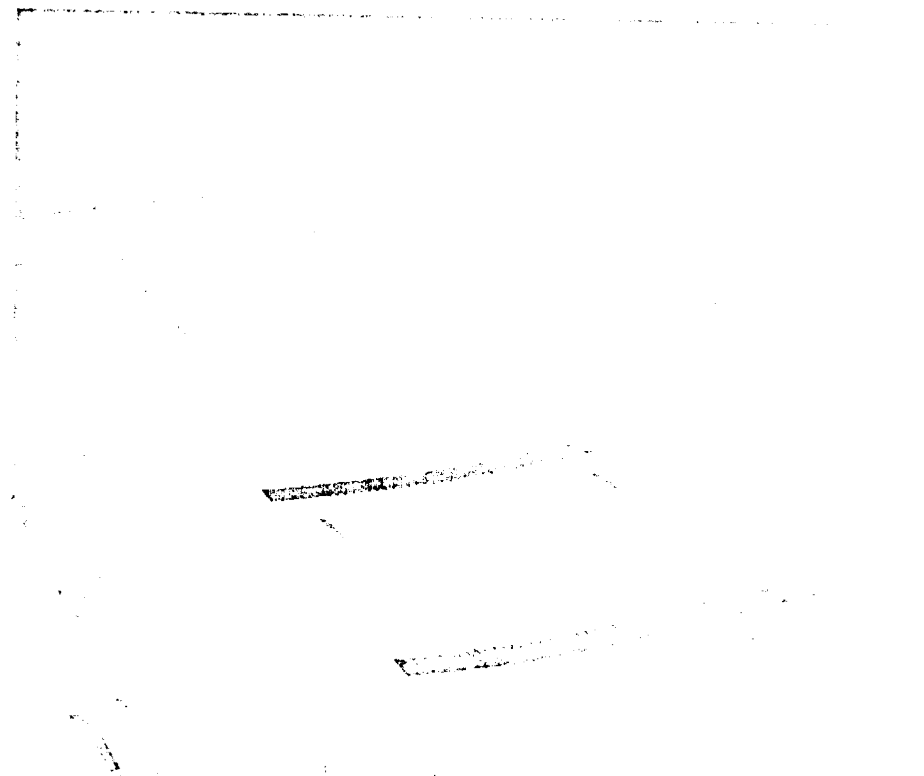


FIGURE 5 Test exposures are examined for density and tonal response prior to making the final master negative.

one half of the total exposure on the fade-in. By using a fade-in, fade-out in the overlap area, it was possible to record eight orbits on one continuous film strip without resorting to mechanical film splicing.

In order to accomplish the precise blending of the two overlapping sections, Aero Service designed a special metering and registration device for measuring and maintaining alignment of the film as it is advanced across the focal plane. (See Figures 6 and 7, Page 15) The first exposure required 27.75" of film (360 degrees of longitude, plus 10 degrees of overlap) while the succeeding exposures each required exactly 27 inches of film. At the final film scale of 800 nautical miles to the inch, 27 inches is equivalent to one complete earth orbit. The film lengths of Rolls A and B, including leaders and trailers, are 50 feet each.

<u>Fade Band and Moonlight Effects</u>. During each orbit of the training mission, the astronaut will pass through a sunlit and moonlit or night phase. The method used in the simulation of the transition from sunlight to moonlight and back to sunlight again was one of several methods specifically tested for this project. The method offering the most realistic

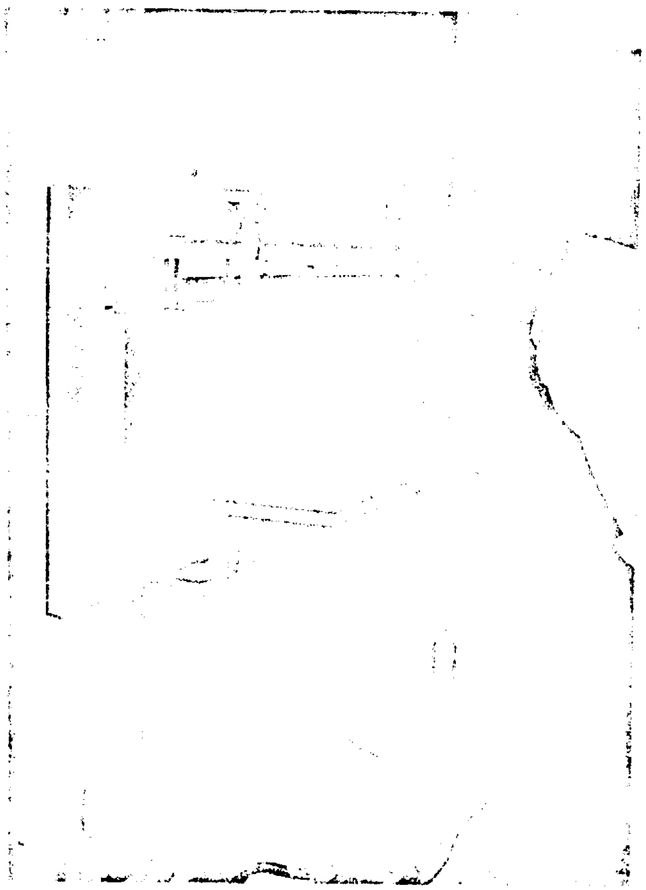


FIGURE 6 Vacuum back and Aero designed metering and registration device. (Vacuum back open) The technician is sighting through one of the two microscopes of the registration device.

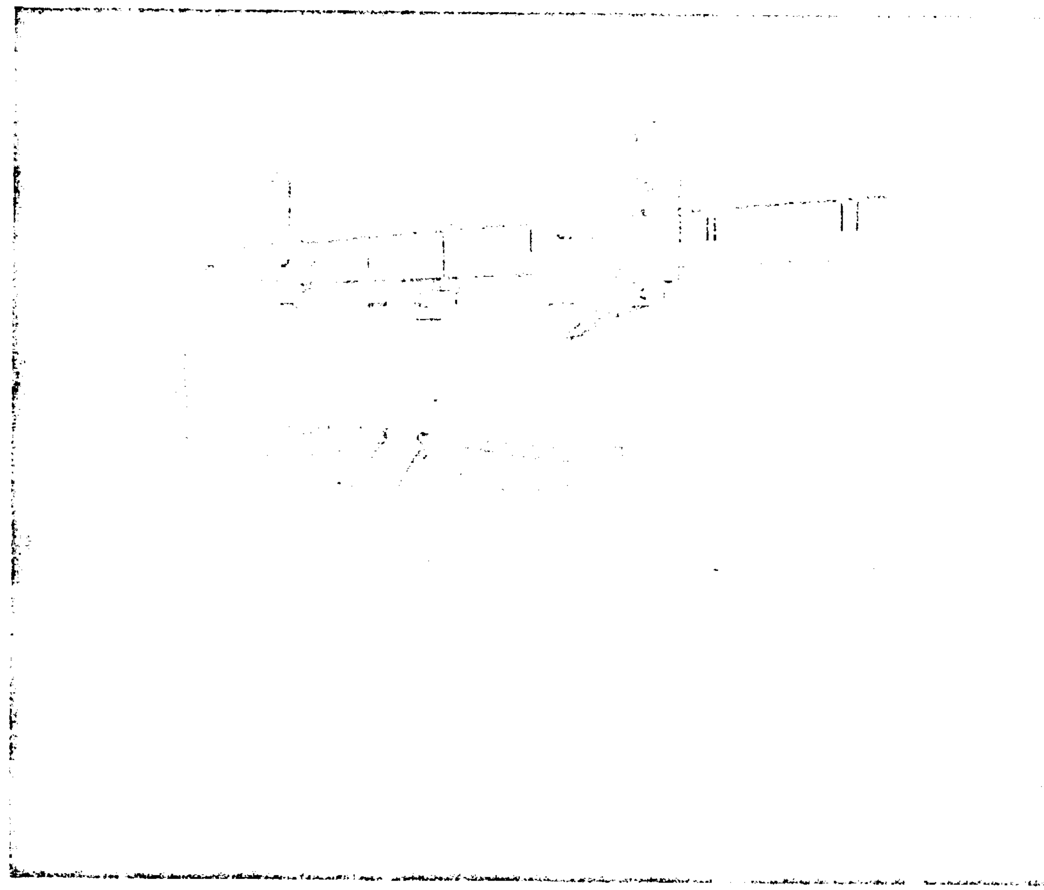


FIGURE 7 Vacuum back film holder (closed) and metering and registration device mounted on the Robertson Tri-Color Camera.

transition, and the one used, was adjustable masking baffles located between the master artwork and the lens of the camera. Movement of the baffles controlled the exposure of the fade bands and moonlit areas.

Master Negative Film Type. For the creation of the master negative, it was necessary to experiment with several types of film having a film speed much lower than the Type SO-226 film, yet still possessing the necessary spectral response and resolution.

After reviewing the technical data and tests of the selected emulsions, it was decided that DuPont Type 228R Cronar Aerial Duplicating Film was the most suitable. However, upon ordering additional footage, the film was found to have an inherent banding effect in the transverse direction. Further tests indicated that Kodak Aerographic Duplicating Film, Type 2427, was more suitable. The Aerographic Type 2427 was used in making the master negatives from which the final terrestrial film graphics was printed. (See Figure 5, Page 13)

Production of the Mirror Image Film. It was determined that the best resolution would be achieved by exposing the film in normal camera orientation. The required reversal of the "B" rolls was, therefore, achieved by reversal printing in the Log Etronic SP 10/70A Strip Printer.

Printing of Positive Film Graphics. The final film graphics were printed from the master negative on the Log Etronic SP 10/70A Strip Printer and processed in the Kodak Versamat Processor. (See Figures 8 and 9, Page 18) The necessary contrast ratio, as selected at a meeting at Farrand Optical Company with representatives of NASA and Grumman Aircraft, was attained through sensitrometric tests to achieve the specified gamma and average density level. Considerable difficulty was encountered in attaining tracking of the master negative and SO-226 print film within the 0.02" alignment tolerance. Also, high voltage charges building up in the film attracted dirt particles. To eliminate the problem, two ionizing devices were installed in the printer to neutralize the charge. Numerous other precautions were taken to achieve a very clean positive magenta print. Figure 10, page 19 is a sample of the terrestrial graphics.

Calibration Photographs. The specifications indicated that five 8 x 10 inch calibration photographs be provided for each earth orbit. Since there are eight orbits on Roll A and eight

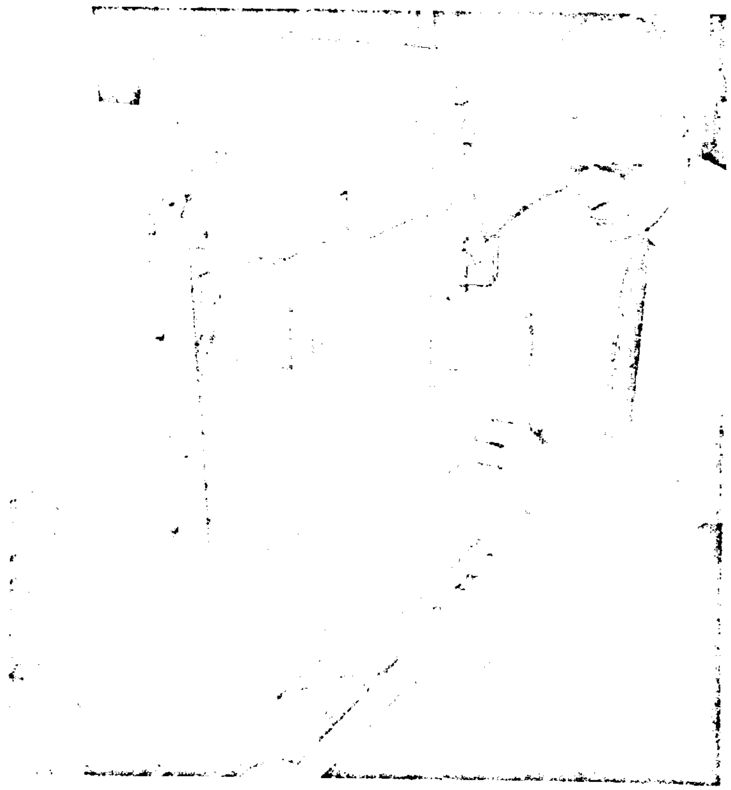


FIGURE 8 Photo Lab technician operating the SP 10/70A Log Etronic printer. The SP 10/70A was used to print the film graphic positives from the final master negatives.

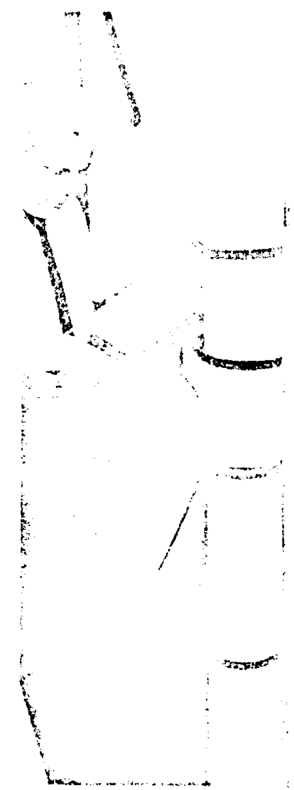


FIGURE 9 Kodak Versamat Processor. The Versamat was used in processing all film graphic negatives and positives.

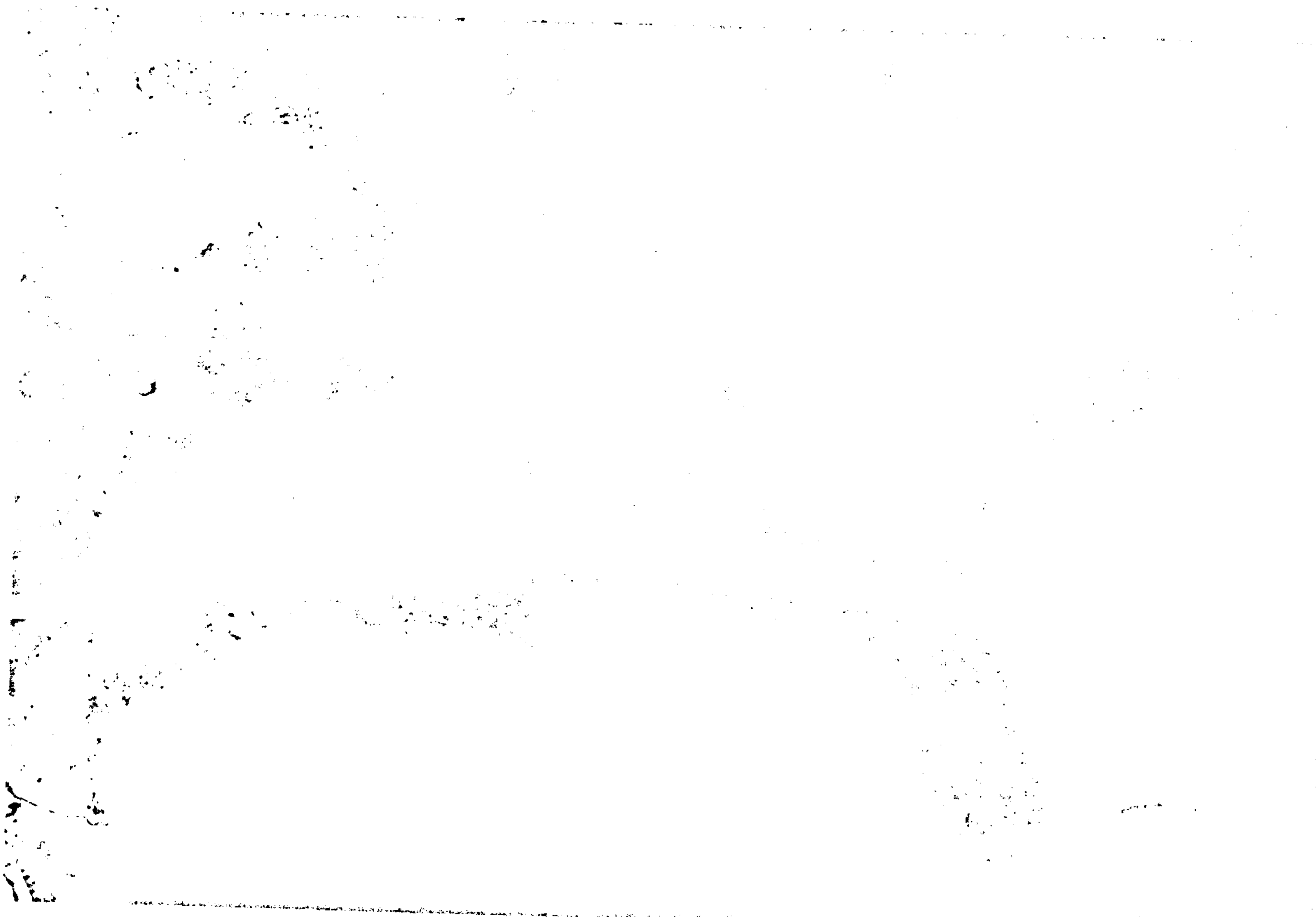


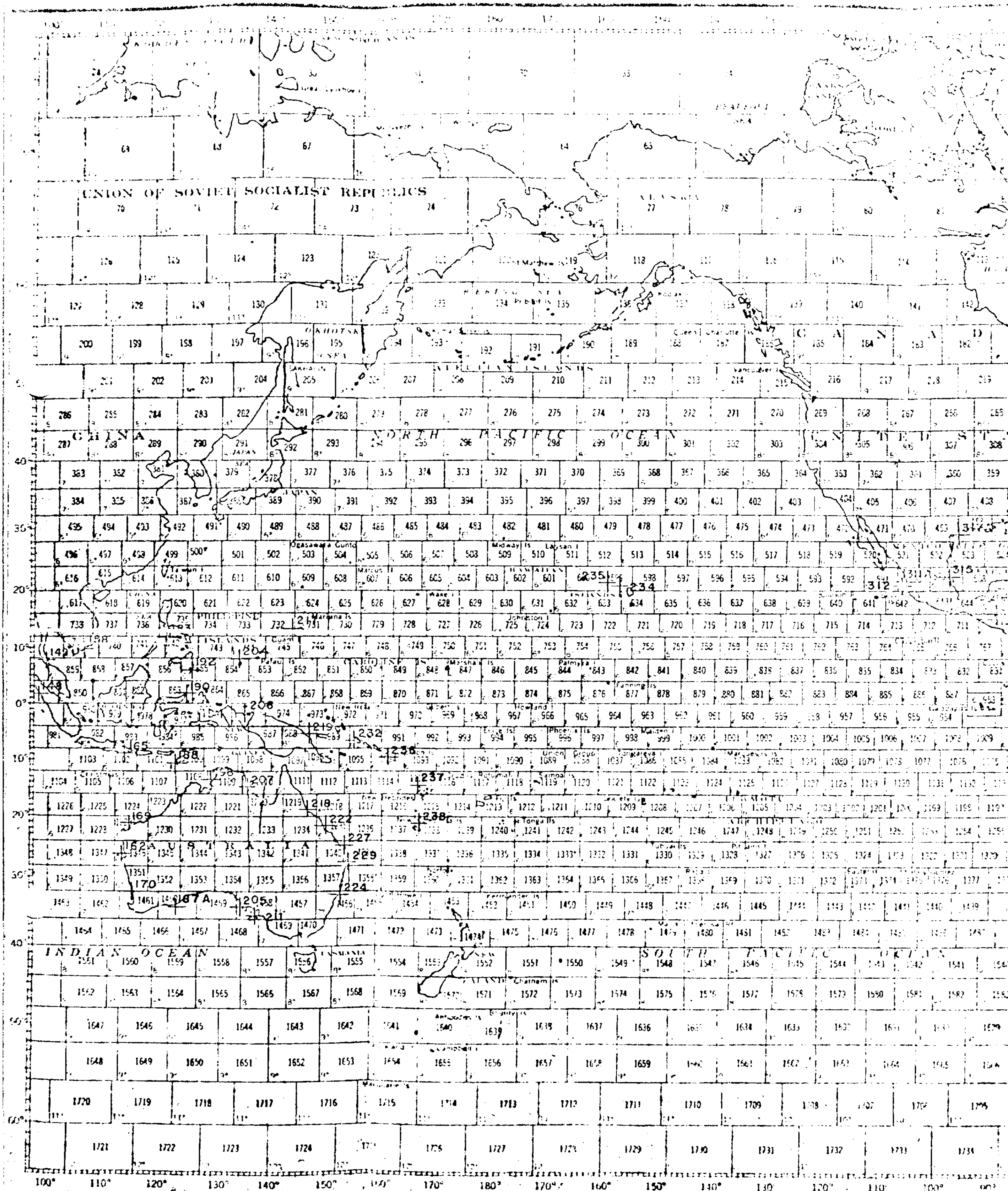
Figure 10 Sample of Terrestrial Graphics at Compilation Scale (1:11,665,920)

on Roll B, a total of 80 calibration photos were furnished. Each photograph is a 15.38 times enlargement from the final negative and the landmark is identified by a high contrast line reticle at the center of the photograph. The calibration photographs also contain the landmark number, a north arrow and on the reverse side, the geographic coordinates of the landmark. (See Figure 11, Page 21)

The 80 selected landmarks are annotated and labeled on a World Aeronautical Chart Index (Figure 12, Page 22).

Figure 13, Page 23 is a contact print of the earth from the final terrestrial graphics negative.

Figure 11 Terrestrial Calibration Photograph



WORLD AERONAUTICAL CHART

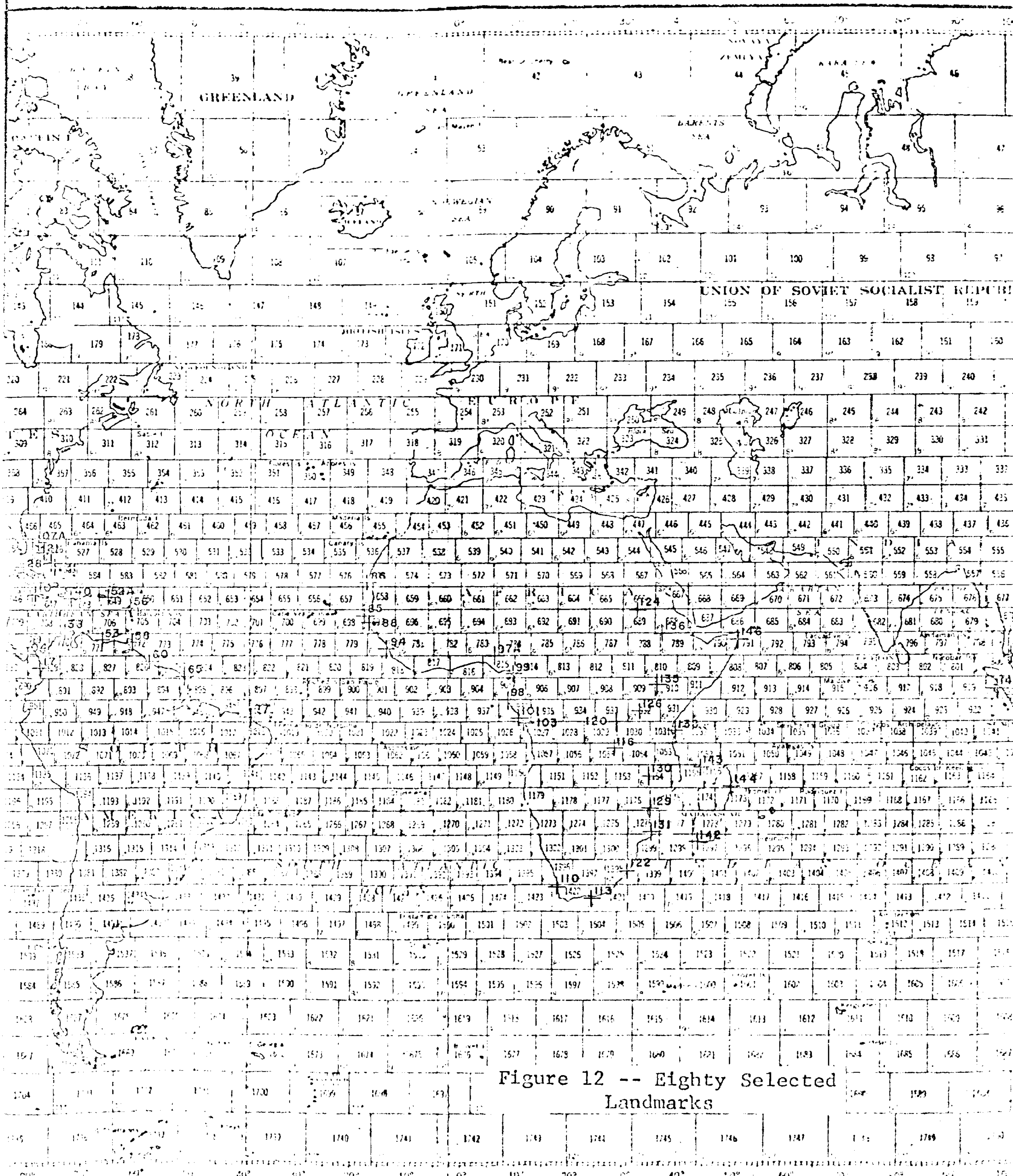


Figure 12 -- Eighty Selected Landmarks

INDEX

Figure 13 Contact Print from Final Terrestrial Negative

To eliminate repetitive compilation and rendition of duplicate scene coverage and to insure point to point correspondence between Lunar Ranges, two adjacent altitude ranges were rendered as a composite scene.

The two orbital Ranges 1 and 2 were compiled and rendered as a single unit. This was possible because Range 2 (larger final scale than Range 1) falls within Range 1. However, since Ranges 1 and 2 were required at three different lunar phases, it was necessary to compile and render three distinct manuscripts. Similarly, the two sub-orbital altitude Ranges 4 and 5 were compiled and rendered as a single unit. There are ten individual master artworks (one for each landing site) for Range 4 and Range 5. Range 5, being at a lower altitude, falls within Range 4. Individual artworks were produced for sub-orbital Range 3 and consists of three scenes, one for each lunar phase. For the landing and ascent scene, a single master artwork was compiled.

A total of 17 master artworks, encompassing all the specified ranges and lunar phases, were rendered.

Compilation of Master Data Base

Original Source Data. Research into good quality, large scale lunar source data, revealed that very little large scale source material was available. The charts which were available included the Apollo Intermediate Charts at a scale of 1:500,000; and the Ranger Lunar Charts which vary in scale from 1:1,000,000 to 1:1,000. Only five charts in each series have been produced to date. These charts covered only a small portion of the lunar surface which was to be rendered and it was necessary to use as the primary source material, the Lunar Astronautical Charts at 1:1,000,000, produced by ACIC. The extent of coverage of the 1:1,000,000 LAC charts (See Figure 14, Page 26) is approximately 32 degrees north and south of the lunar equator. For the area beyond the LAC coverage, it was necessary to employ the 1:5,000,000 AMS Topographic Lunar Map.

Other source material used by the renderers in their depiction of the lunar landscape consisted of Ranger VII and VIII photographs, the Rectified Lunar Atlas, and telescope photographs obtained from Lick Observatory.

Construction of Compilation Projection Grids. Both intermediate and final master grid projections were accurately plotted and

Film Graphics Source

LAC'S	Edition	Date	
38	1st	March	1965
39	1st	November	1963
40	1st	October	1963
41	1st	September	1963
42	1st	February	1965
43	1st	May	1965
44	1st	December	1965
56	1st	May	1963
57	2nd	May	1962
58	2nd	April	1964
59	1st	April	1963
60	1st	September	1962
61	1st	February	1963
62	1st	February	1964
74	1st	April	1962
75	2nd	June	1962
76	2nd	April	1964
77	1st	May	1963
78	1st	March	1963
79	1st	April	1963
80	1st	March	1964
92	1st	February	1966
93	1st	June	1962
94	1st	May	1964
95	1st	December	1964
96	1st	April	1965
97	1st	May	1965
AIC'S			
58C	1st	May	1965
58D	1st	March	1965
59C	1st	January	1966
60D	1st	May	1965
77A	1st	May	1965
R VII LC'S			
RLC 2	1st	October	1964

Figure 14

scribed on the Haag-Streit Coordinatograph in the same manner as in the Terrestrial Film Graphics.

A separate master grid projection was constructed for each of the lunar scenes. The compilation scales, format sizes, etc. are shown in Figure 15, Page 28.

The compilation scales and formats shown in Figure 15 were computed utilizing the final film scales, length, and specified longitudinal extent for each of the altitude ranges.

Paneling of Original Source Data. The general paneling procedures, as described for the compilation of the terrestrial master data base, was essentially the same for the lunar scenes. The original map source information was paneled in strips to an intermediate compilation grid. These strips were then photographically enlarged or reduced to a common compilation scale. The negative strips were then assembled on a mylar overlay which was punch registered to a master projection grid. The completed master negative assembly was then photographically transferred to a stable base photo sensitized material which was punch registered to the rendering base.

The Landing and Ascent scene was rendered first and reduced copies were made at the compilation scale of Ranges 4 and 5.

Lunar Scales and Dimensions

Range	Phase	Manuscripts	Compilation Scale	Dimensions			Final Scale (N.M. = 1 in.)	
1	A	1	1:2,136,256	46.90"	x	145.77"	252.1	N.M.
	B	1	1:2,136,256	46.90"	x	132.31"	252.1	N.M.
	C	1	1:2,136,256	46.90"	x	109.50"	252.1	N.M.
2	A	(Within Range 1)		22.5"	x	145.77"	73.5	N.M.
	B	(Within Range 1)		22.5"	x	132.31"	73.5	N.M.
	C	(Within Range 1)		22.5"	x	109.50"	73.5	N.M.
3	A	1	1:495,250	22.5"	x	79.525"	16.97	N.M.
	B	1	1:495,250	22.5"	x	112.475"	16.97	N.M.
	C	1	1:495,250	22.5"	x	81.150"	16.97	N.M.
4	A	4	1:129,577	22.5"	x	71.40"	4.44	N.M.
	B	3	1:129,577	22.5"	x	71.40"	4.44	N.M.
	C	3	1:129,577	22.5"	x	71.40"	4.44	N.M.
5	A	(Within Range 4)		11.7"	x	37.713"	2.312	N.M.
	B	(Within Range 4)		11.7"	x	37.713"	2.312	N.M.
	C	(Within Range 4)		11.7"	x	37.713"	2.312	N.M.
6		1	1:8,828	45.0"	x	60.0"	.605	N.M.

Total Manuscripts - 17

Figure 15 Lunar Scales and Dimensions

Since Ranges 4 and 5 constitute ten different compilations (one for each landing site), the reduced Landing and Ascent negative was reproduced for each of the scenes and incorporated in the negative assemblies. This procedure insured a point to point correspondence and a smooth transition from any one of the ten selected landing sites to the Landing and Ascent scene.

In a similar fashion, as each of the ten scenes were compiled and rendered for Ranges 4 and 5, they, in turn, were photographically reduced and incorporated as part of the negative assemblies of sub-orbital Range 3.

Rendering of Lunar Artwork

Shadow Geometry. The orientation and length of a cast shadow was determined by the direction of incident sunlight and the position of a vertical structure upon a spherical surface. The direction of the incident sunlight was defined by the sub-solar point. The position of a given vertical structure can be defined in terms of its Latitude and Longitude. The geometric considerations are shown in Figure 16, Page 30. In the figure, a right spherical triangle enclosed by sides a, b, and c defines a general point, P, on the surface of the sphere with respect to a reference point X. The reference point is the

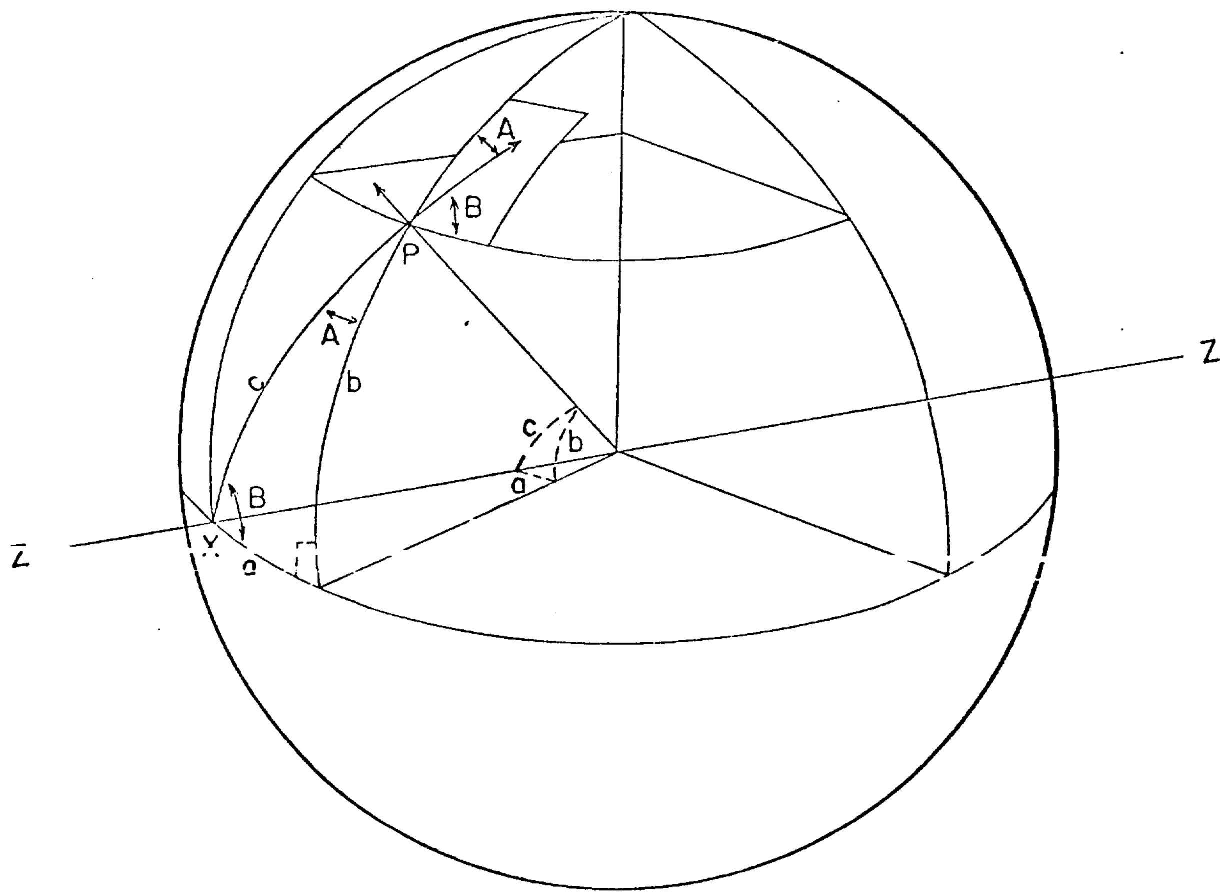


Figure 16 Shadow Geometry

sub-solar point and the direction defined by ZZ' is the direction of the incident sunlight. The sides of the spherical triangle on the surface are angular measures referred to the center of the sphere. Side a is the latitude of the general point, P, and side b is the difference in longitude between the sub-solar point and the longitude of P.

At the general surface point, P, a local orthogonal coordinate system is defined by:

1) the Normal to the surface at point P
2) the direction of the local meridian
3) the direction of the local parallel of latitude

On the final graphics which are flat, the latter two form an orthogonal pair of coordinates over the entire scene. It is with respect to this coordinate system that we determined the length and orientation of the cast shadow.

In order to determine the shadow length, it was first necessary to determine the angle between the direction ZZ' and the local normal. This angle is equivalent to side c and is readily determined from the identity:

$$\cos c = \cos a \times \cos b$$

The shadow length was then obtained from the following relationship:

$$\text{Shadow Length} = (\text{object height}) \text{ TAN } c$$

The orientation or angle the shadow makes with one of the axes in the locally horizontal plane is equivalent to the Angle A when measured from the local meridian and equivalent to Angle B when measured from the local parallel. These angles are determined from the identities:

$$\text{COS } A = \text{TAN } b/\text{TAN } c$$

$$\text{SIN } B = \text{SIN } b/\text{SIN } c$$

These basic equations permitted the computation of the magnitude and direction of the cast shadows. Since all shadows radiated generally away from the sub-solar point which is the reference point, it was necessary to calculate only one quadrant since the other three quadrants are mirror images. The direction and magnitude of the cast shadows is shown graphically in Figure 17, Page 33 which is a vector diagram computed for ten degree intervals of Angles A and B.

Lunar Surface Shadows. In the previous section, treating shadow geometry, the situation was necessarily idealized to describe the geometrical situation. Further clarification was required to depict actual lunar terrain.

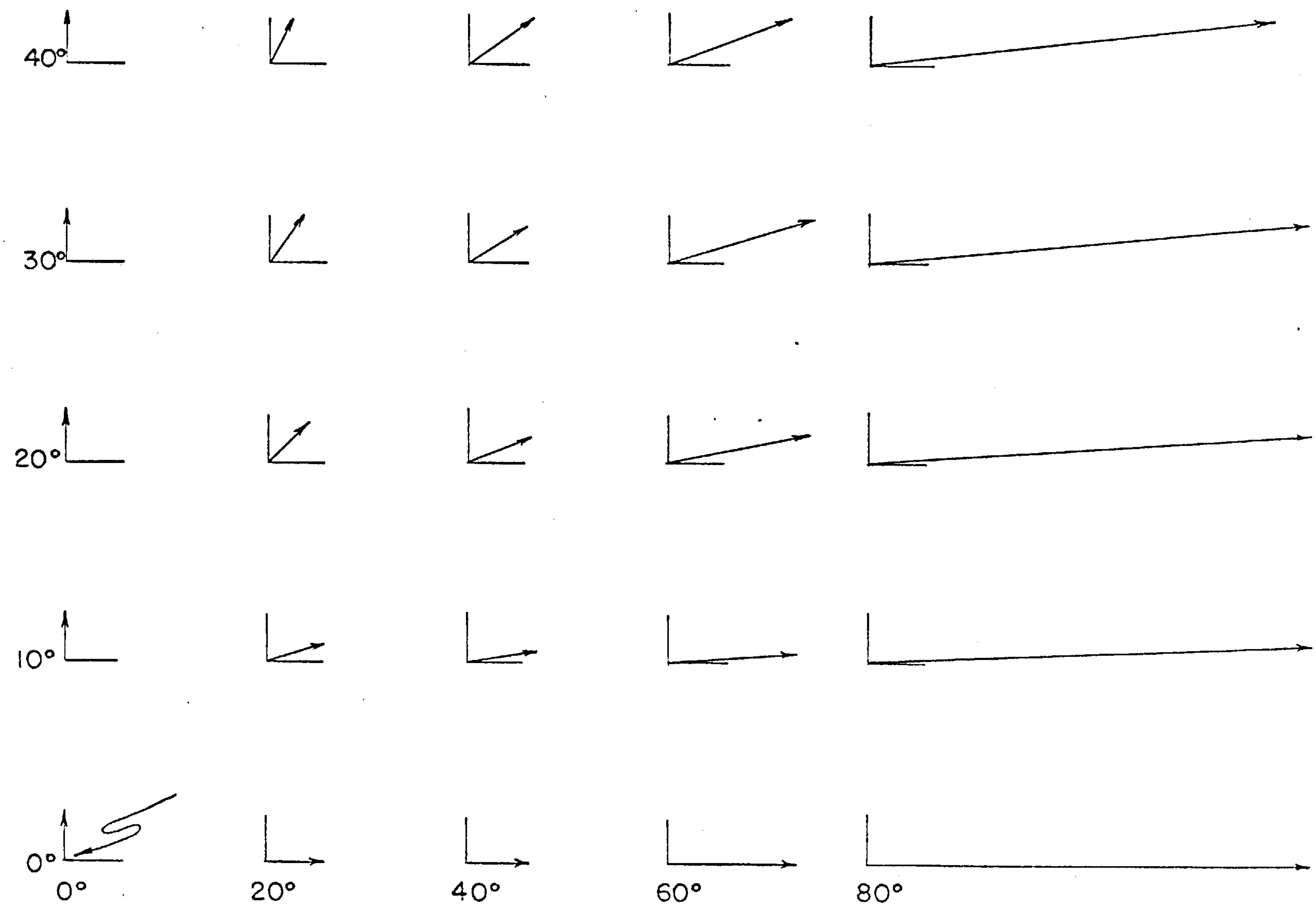


Figure 17 Shadows shown as vectors versus angle "a" and angle "b"

The lunar surface is composed largely of irregular sloping terrain. On the basis of various studies of the lunar surface, structure slopes of about ± 15° are expected over much of the lunar surface.

In order that actual shadows be produced, the angle of incident sunlight must be less than the angle of slope of the terrain. Consequently, large sloping craters and other features having similar slopes actually cast no shadow unless located within 15° of the terminator.

Although no shadows are cast in the area from 0° to 75° from the sub-solar point, differences in illumination are present. These differences are principally due to differences in reflectivity of the materials which make up the lunar surface and the variation in the angle of incidence of the sunlight.

<u>Defining Shadow Direction</u>. The area covered by the sub-orbital altitude Ranges 4 and 5, includes the ten landing sites which are generally located within two degrees of the lunar equator. Within this latitude range, the shadow orientation is practically constant and was so depicted for each of the ten landing site scenes. Of course, differentiation of shadow direction was made for those points which appeared above and those which appeared below the lunar equator. Sub-orbital Range 3

encompassed a latitudinal extent of approximately 5 degrees above and below the lunar equator. For this altitude range, the shadow direction was defined as a constant for each one degree of latitude by 5 degrees of longitude. That is to say, each area was considered as being a horizontal plane upon which the relative shadow positions were a constant. This same procedure was employed for the orbital altitude ranges within the latitudinal extent of 5 degrees on either side of the equator. Beyond 5 degrees of the equator, the shadows were depicted as having a constant orientation for each 10° x 10° interval of latitude and longitude.

Determining Shadow Lengths. The length of the shadows are directly proportional to the tangent of the incident light angle. In the sub-orbital altitude ranges which are contained within a latitudinal band of 5 degrees of the equator, the incident light angle is primarily a function of the difference in longitude between a specified point and the sub-solar point. The tangent of the incident light angle was computed at a constant mid-latitude of 2½ degrees. A series of curves were then constructed which defined the shadow length as a function of longitude and vertical height. A similar approach was employed for the orbital altitude ranges.

The angular orientation of the cast shadows and corresponding length were annotated as vectors on the intermediate rendering data base. The personnel assigned to this task determined the height of the various lunar features by interpretation of the elevation contours. Additionally, these personnel determined the approximate position in terms of latitude and longitude and utilized the appropriate graph to determine the shadow length.

Rendering of Gray Scales. The rendition of the lunar landscape was basically the rendition of light and shadow effects. The differences in tone, or gray scale, not only reflected the differences due to relief but also the differences in the reflectance properties of the specified areas.

The portrayal of shadows required a great degree of artistic and cartographic judgement on the part of the renderers. The judgement was necessary when one considers that the shadows are affected not only by the lunar phase and object height but also by the surface irregularity and slope. In addition, much of the original source material was without elevation contours and at such small scale that artistic interpretation was necessary.

Method. The 17 lunar scenes were rendered on a transparent mylar base material superimposed and punch registered with the master compilation base. The actual rendering was accomplished by employing plasticized rendering tools and techniques. (See Figures 18 and 19, Page 38) As visual aids in their artistic interpretation, the renderers used the most up-to-date lunar photographs which included Ranger VII and VIII photographs and other sources such as Lick Observatory telescopic photos and the Rectified Lunar Atlas.

Photographic Copying of Lunar Scenes

Artwork and Camera Alignment. The lunar graphics consists of 17 different scenes compiled and rendered at six different scales. Four different reduction factors were employed in reducing the master artworks to the required final film scales. To insure that the center line of each exposure was accurately positioned, an optical reference center line was placed on the face of the easel.

Continuous Film Strip Procedures. The artworks were copied in the sequence indicated by the specifications. The specially designed film metering and alignment device, which is part of the film holding system, was used in metering the variable lengths of film across the focal plane. This was accomplished to an accuracy corresponding to the positional accuracy of the

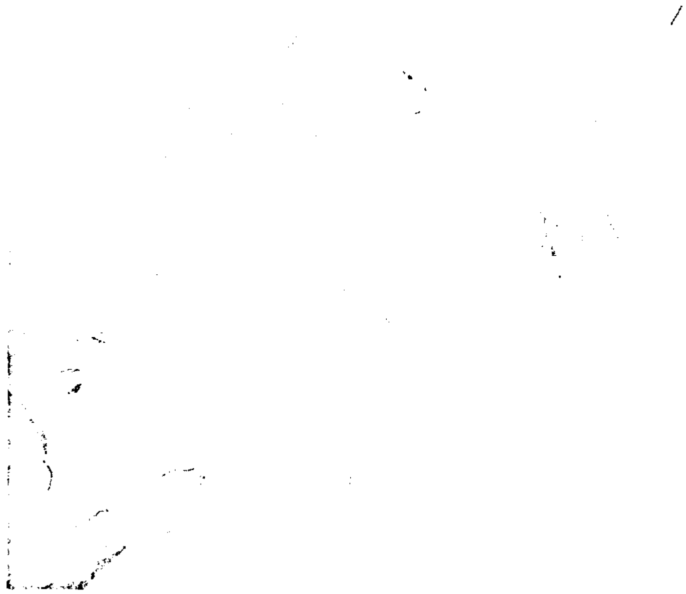
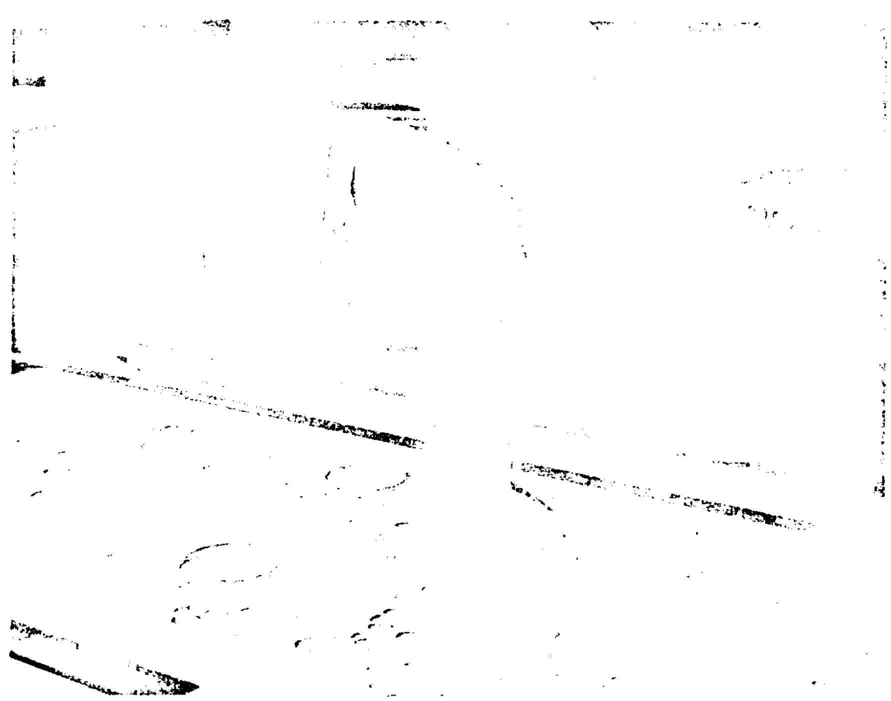


FIGURE 18

(Left) Aero artists, using special plasticized tools, rendering Range 1 of the Lunar graphics.

FIGURE 19

(Right) Artists adding final detail to Landing Site 7, Range 4, Lunar graphics.



sprocket holes in the final film positive.

Film Exposure. The best available optics, Goerz Red Dot Artar Lenses, were used in the optical reduction of the artwork. Due to the extreme image length of Range 1, it was necessary to reduce the artwork in two steps. Optimum aperture settings and monochromatic illumination was utilized to insure the best possible resolution.

Production of a Reversed Image Film Roll. The Lunar reversed image film roll was produced in the same manner as the terrestrial mirror image roll.

The film was exposed in the normal camera orientation and the mirror image film was achieved by reversal printing in the Log Etronic SP 10/70A Strip Printer.

Printing of the Final Lunar Graphics. The master negatives were contact printed on SO 226 film on the Log Etronic SP 10/70A Strip Printer. All required resolution charts, linearity charts, and fiducial patterns were provided as specified. The total length of each roll, including leaders and trailers, is 56 feet. Figure 20, page 40, is a sample of the lunar graphics.

Calibration Photographs. One set of calibration photographs

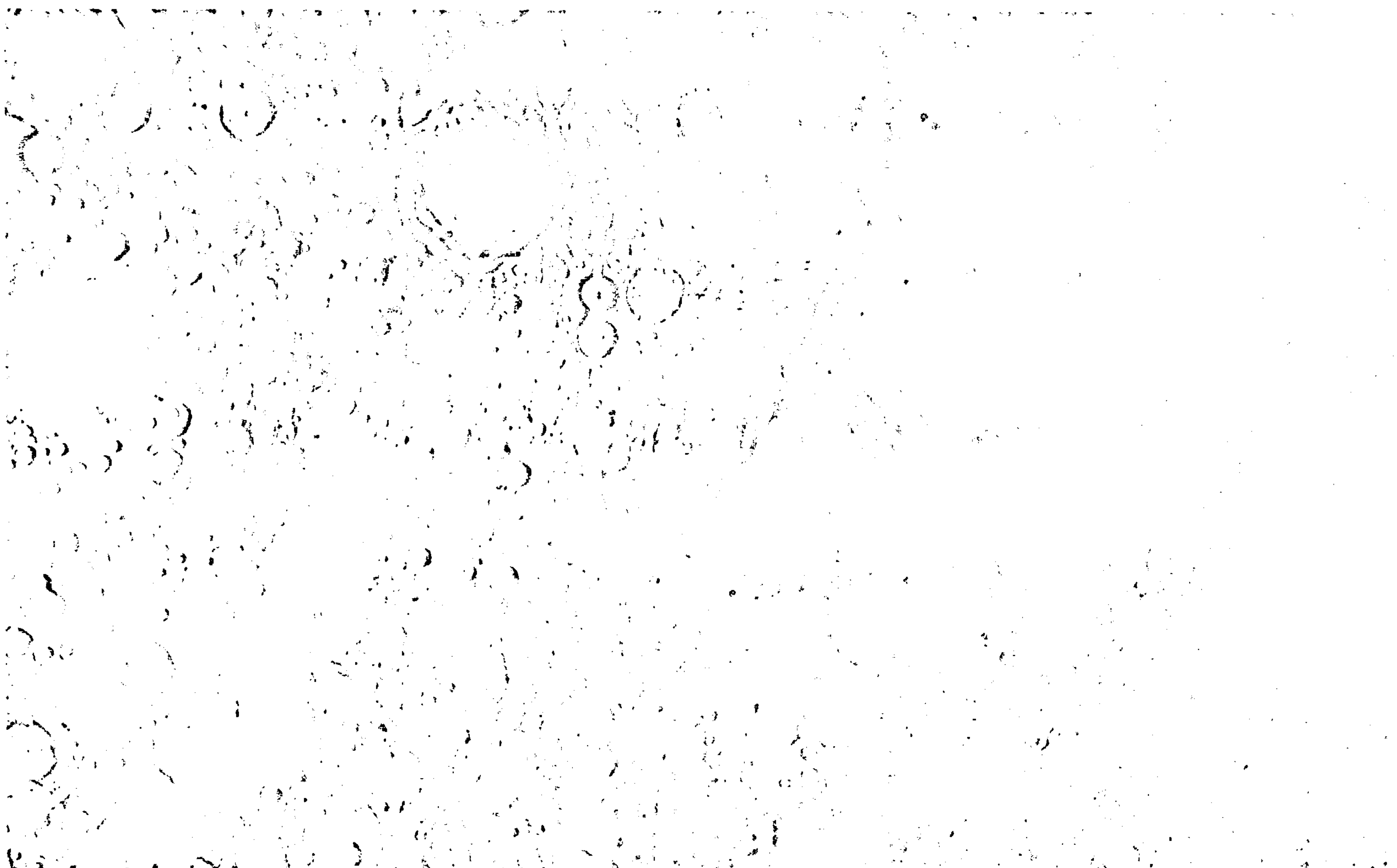


Figure 20 Sample of Lunar Graphics (Range 2, Phase C)

of each landing site at each orbital and sub-orbital range and each lunar phase, was provided. (See Figure 21, Page 42.) The calibration photographs, measuring 8 x 10 inches, show a high contrast line reticle centered on the landing site, a north arrow and for identification, the lunar range, phase, and landing site number. On the reverse, the geographic coordinates of the landing site have been furnished. The calibration photographs are a 15.38 times enlargement from the final negative. Figure 22, page 43, is a lunar map showing the ten landing sites.

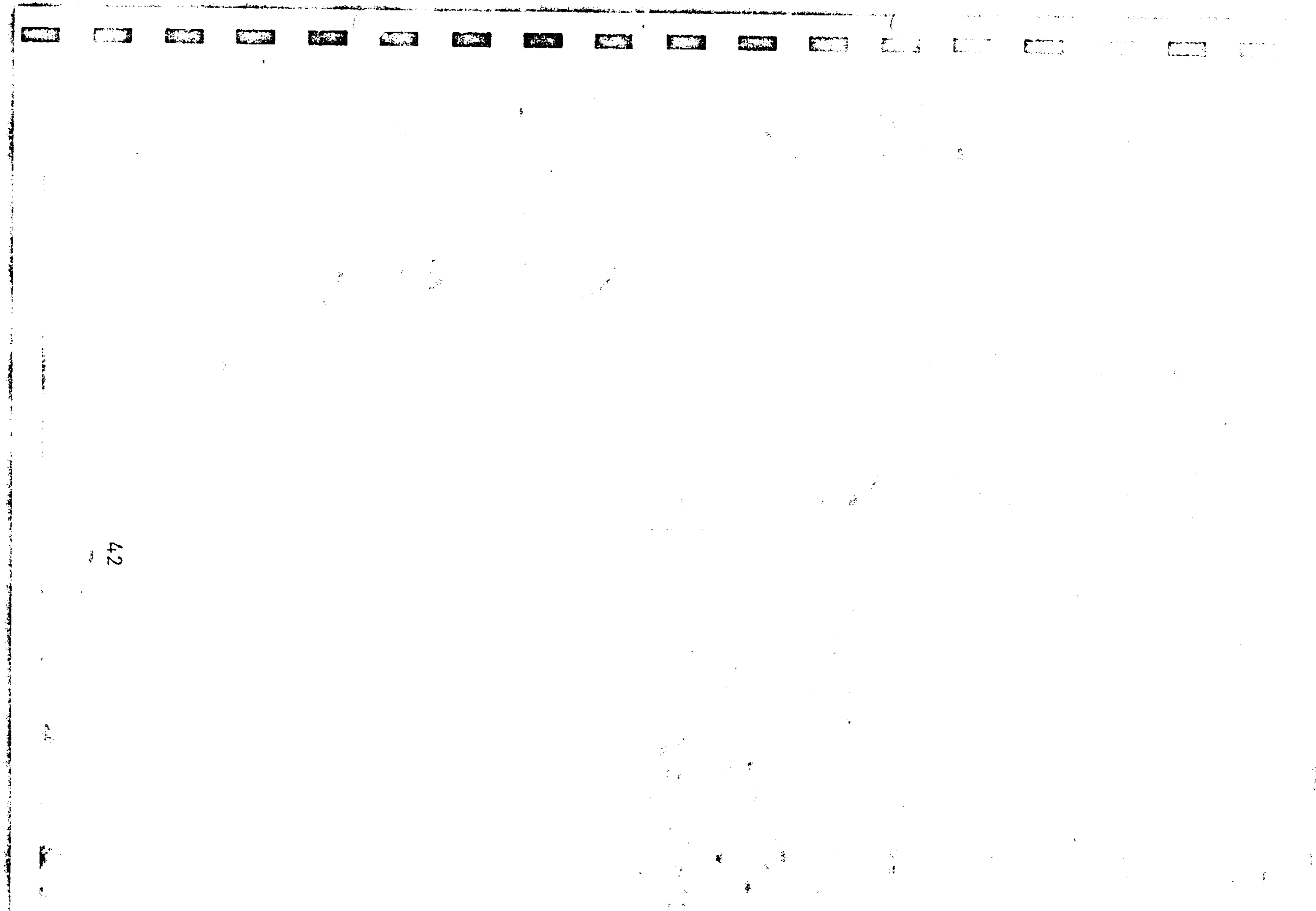


Figure 21 Lunar Calibration Photograph

PHASE

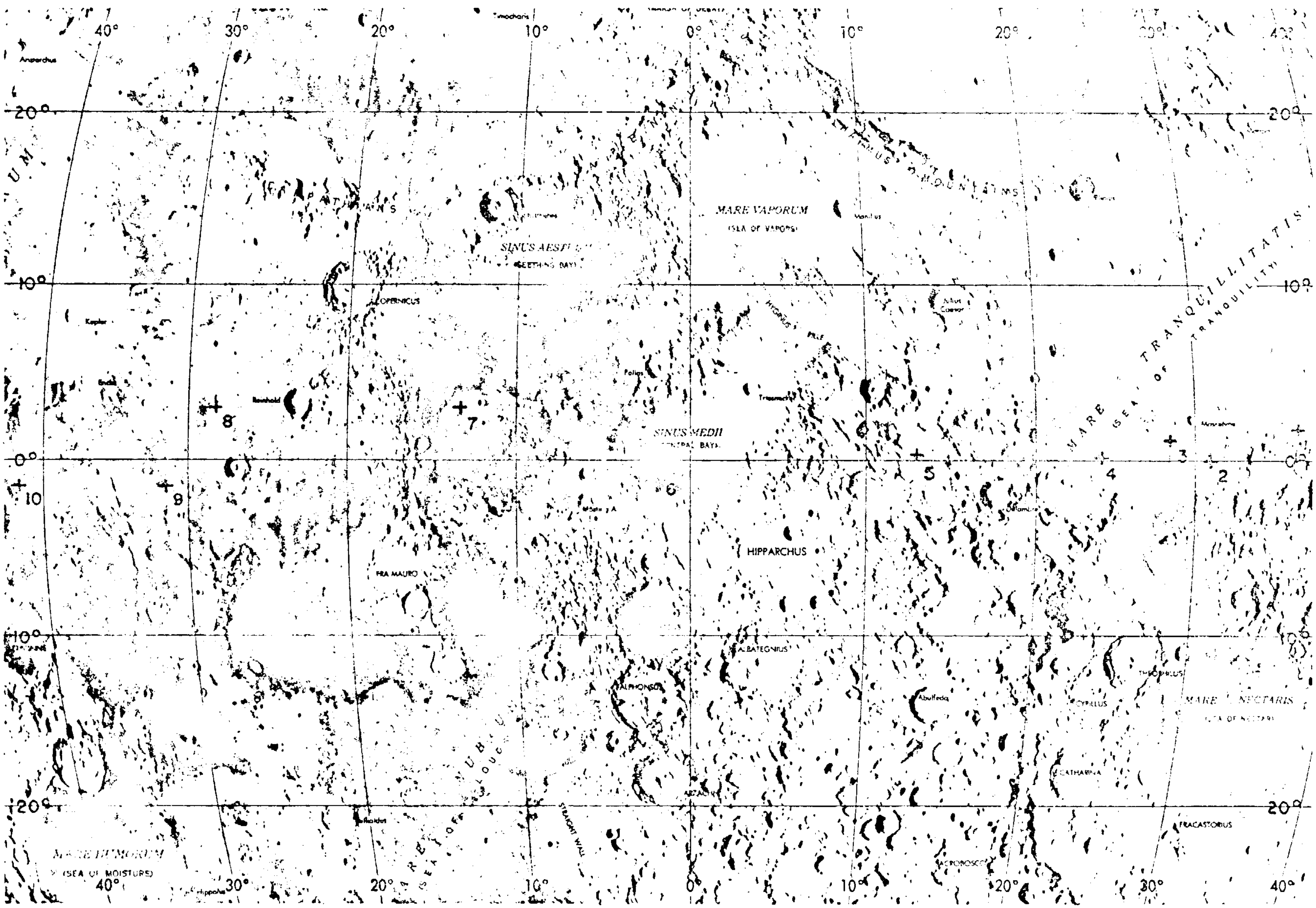


Figure 22 Lunar Landing Sites

SPECIAL TEST FILMS PRODUCED UNDER
CCA NUMBER 6

In July 1967 Aero Service was requested to produce additional Test Films which will be described in this section.

Item I - Image Quality and Resolution Test Film

To produce the series of test films at a number of different contrasts in both black and white and magenta images a master composite negative was first prepared. The master negative contained the following items:

a. An actual sample of the Film Graphic Lunar image selected from a portion of range 1. Size was five inches by five inches.

b. A full scale reproduction of the 1951 USAF Resolution Target reproduced directly from a Gurley Master.

c. An eight time reduction of the 1956 RETMA Chart (T.V. Test Pattern).

d. Two copies of the 1956 RETMA Step Tablet only photographically copied so the tablet was 3.5 inches long. The two step tablets were arranged so the ascending density values were in opposite direction.

Fig. 23 illustrates the data contained on this test film. Overall length of each test film was approximately 18 inches.

The aim was to produce five different contrast test films in both black and white and magenta which would represent the full range of contrast possible from the existing master negative rolls when printed on Eastman SO-226 film.

Initially, five black and white test films were produced, then two additional films were made referred to as B & W Strip 6, 7. These additional strips were made to provide lower contrast levels than those achieved in the first group of five. For the Magenta Dye Coupled images a total of five test films were produced and characteristic curves of these test films is shown in Fig. 24.

Item II Additional Test Films - Eight Foot Length

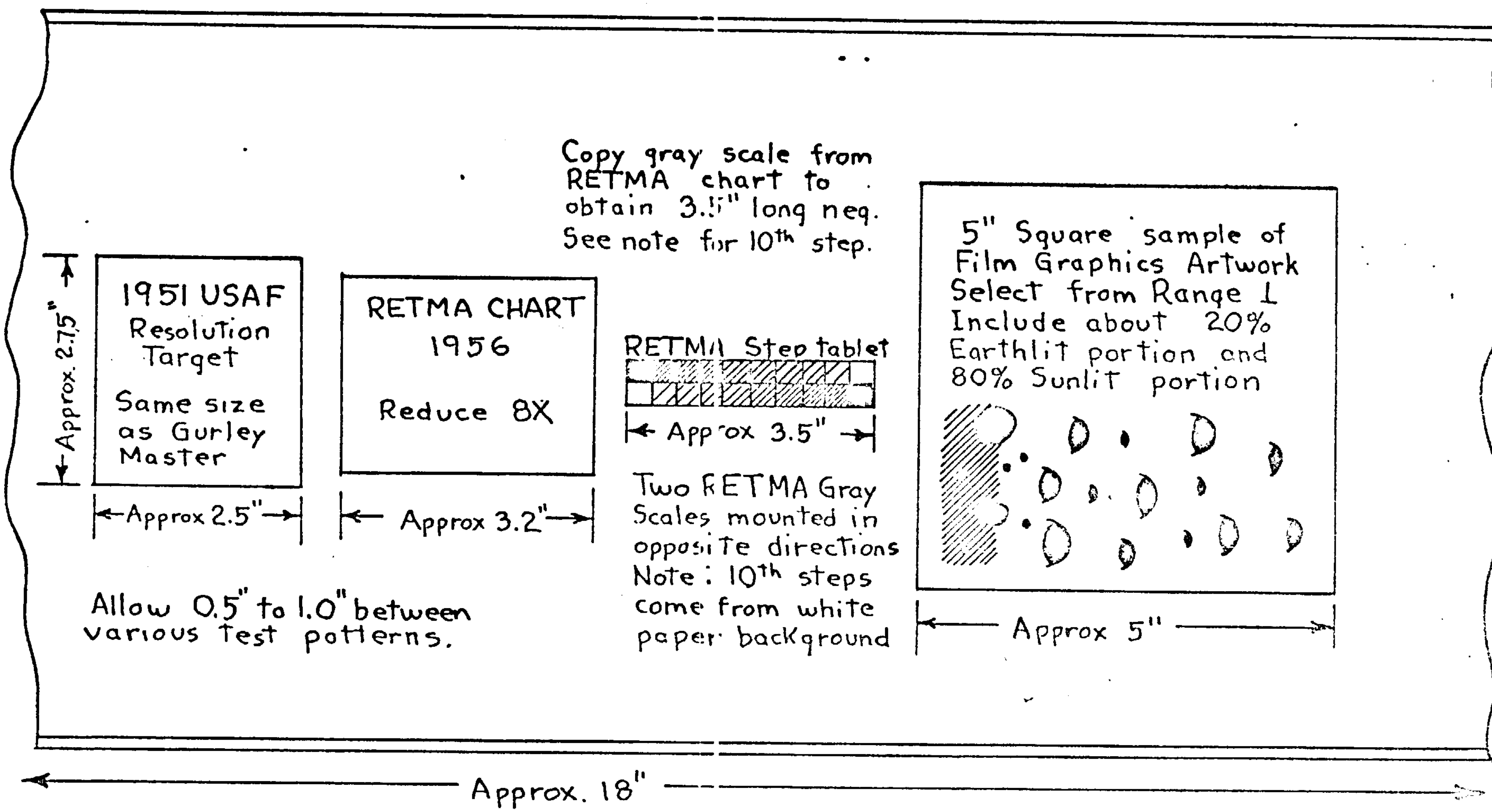
From the same composite test film assembled for Item I one each eight foot length test film was produced in both black and white and magenta. The contrast of each of these films was the same as the respective middle contrast test produced under Item I.

Item III - Percentage Transmission - Test Film

After considering several different formats, the design shown in Fig. 25 was determined by NASA after conference with personnel representing Farrand and Grummand.

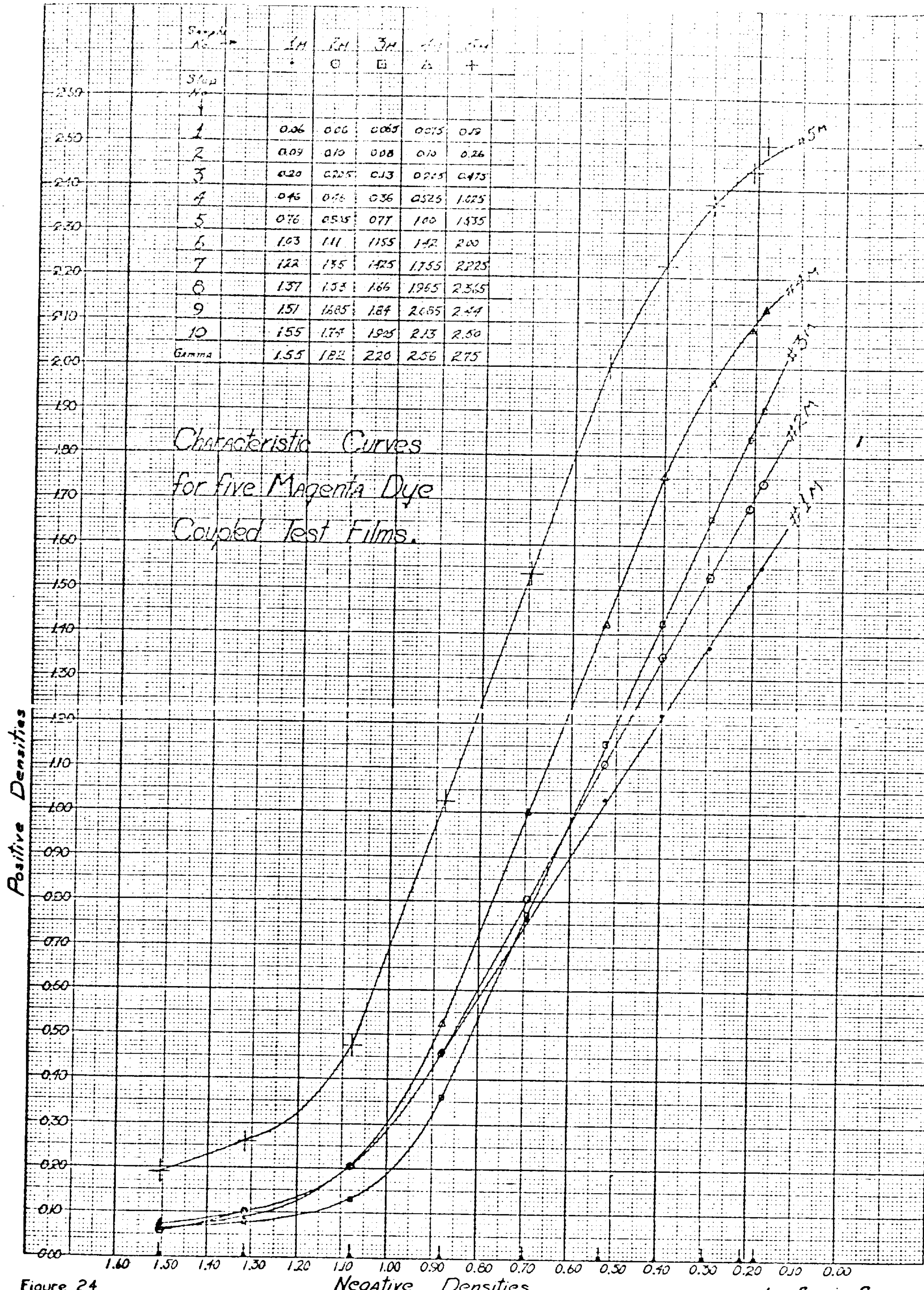
It was necessary to first produce a specified characteristic curve for the SO-226 emulsion stock on hand from which the required (Log E) exposure values and processing time was selected to produce the specified 1%, 25%, 50%, 75% and 90% transmission values.

A second specific characteristic curve for the SO-226 emulsion stock on hand was produced but continued through the black and white processing to a magenta dye image by magenta dye coupling. From this curve the specific (Log E) exposure values and processing time was selected to produce the specified magenta image 1%, 25%, 50%, 75%, and 90% transmission values.



½ Scale Drawing for NASA
Film Graphics Test Items 1 and 2

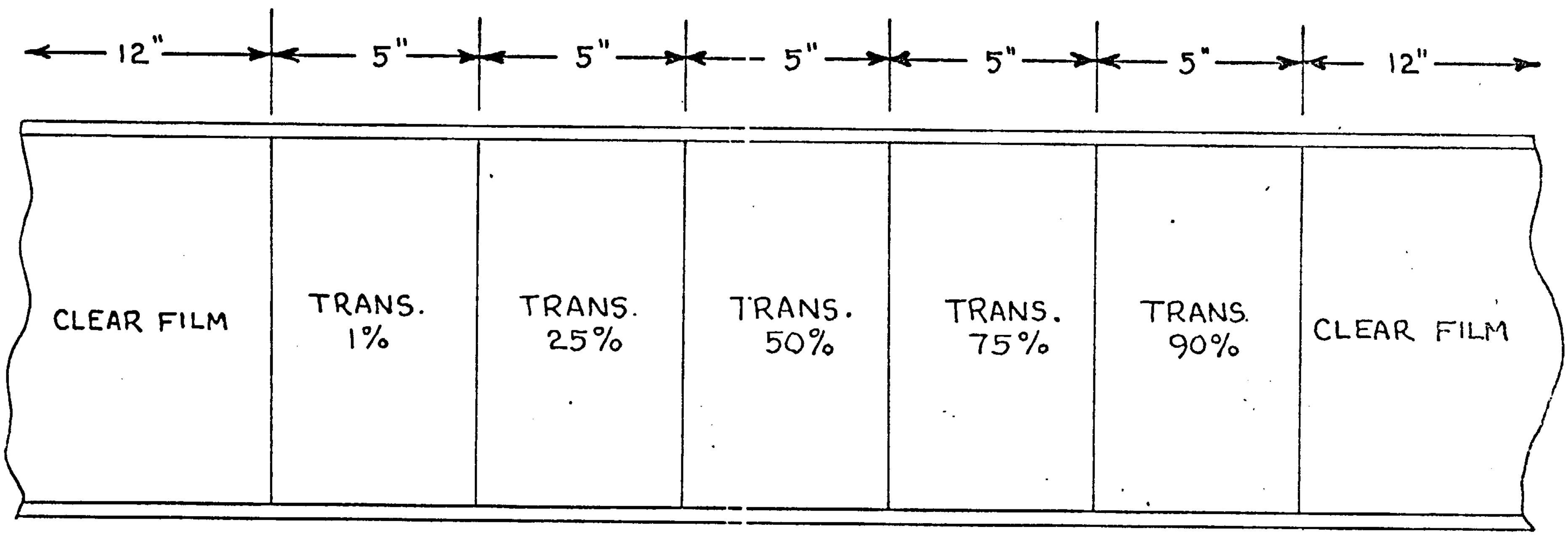
FIGURE 23



Sample No. →	1M •	2M ○	3M □	4M △	5M +
Step No. ↓					
1	0.06	0.06	0.065	0.075	0.19
2	0.09	0.10	0.08	0.10	0.26
3	0.20	0.225	0.13	[illegible]	0.475
4	0.45	[illegible]	0.36	0.525	1.025
5	0.76	0.535	0.77	1.00	1.535
6	1.03	1.11	1.155	1.42	2.00
7	1.22	1.35	1.425	1.755	2.225
8	1.37	1.53	1.66	1.965	2.365
9	1.51	1.685	1.84	2.065	2.44
10	1.55	1.74	1.925	2.13	2.50
Gamma	1.55	1.82	2.20	2.56	2.75

Figure 24

Aero Service Corp.



ITEM #3 AS CHANGED BY NASA AFTER
CONFERENCE WITH FARRAND AND GRUMMAN

FIGURE 25

On November 30, 1967 CCA Number 3 was issued to Aero Service which stated:

1. The Contractor shall deliver two 4" x 8" film graphics samples of lunar range 4 on doubly perforated GFE Kodak film type SO-226. One sample shall be processed in black and white, the other sample shall be in magenta, using a magenta dye transfer process from black and white. Each sample shall consist of one half of the image area with significantly enhanced additional detail based upon Orbitor photography and the other half will contain the same detail developed under the above-numbered contract.

2. The objective of the enhanced detail area shall be to produce in an authentic random size and authentic random quantity detail which is comparable to Orbitor photography.

3. The techniques used to produce the above items shall be capable of being applied to the production of film graphics for use in the Mission Effects Projector and shall not be uniquely associated with the production of the item deliverable hereunder.

4. The Contractor shall furnish the material cost and labor hours expended in the production of the enhanced film graphics and also for the unenhanced film graphics.

5. The Contractor shall furnish a description of the technique used in supplying the enhanced detail.

Aero Service developed a technique for satisfying the above defined test strips and made delivery of both a black and white and magenta enhanced detail sample of a four inch by eight inch image area selected from range 4 on January 11, 1968.

At the completion of the work performed under CCA Number 3 a report was prepared and submitted in January 1968. A copy of this report with minor changes is included as part of this final report.

FEASIBILITY STUDY,

TECHNIQUE FOR DETAIL ENHANCEMENT

OF LUNAR FILM GRAPHICS:

CONTRACT NO. NAS-9-5981, CCA#3

Submitted to :

National Aeronautics & Space Administration

Manned Spacecraft Center

Houston, Texas 77058

Aero Service Corporation
Division of Litton Industries
4219 Van Kirk Street
Philadelphia, Pa. 19135

INTRODUCTION

Recent successes experienced by the Lunar Orbiter Systems have provided photography of the lunar surface with detail never before recorded. The availability of this data raises an immediate question. How can this new data be quickly incorporated into the current training of the Apollo Mission Crews, so that they may have the benefit of the most accurate and up-to-date simulation?

This report describes a technique developed by Aero Service Corporation to up-date the existing Film Graphics by incorporating the improved source information provided by Orbiter Photography. A portion of Lunar Range 4 Artwork was selected for the experiment. Using available Lunar Orbiter Photography as source material, Aero Service Corporation enhanced one-half of the selected area. The remaining half was left unaltered to serve as a reference for comparison purposes. The result was a significant improvement of lunar detail and forms. The techniques employed are described in the following paragraphs.

PRELIMINARY PHOTO PROCESSING

Initial effort involved examining available Orbiter Photography for coincidence with any of the ten (10) landing sites depicted on the Range 4 Artwork. A 4" by 8" area of Range 4 was chosen for its similarity with the typical lunar forms depicted in the Orbiter Photography.

The Orbiter source photography and the Film Graphics sample existed at different scales. For best results it was decided to bring both the sample and the source to the same working scale. Negatives of the Film Graphics sample at a scale of 1:323,735 were photographically enlarged to a working scale of 1:64.747. This five (5) times enlargement was made on a Cronaflex film material chosen for its stability, translucence and compatibility with artistic rendering.

The Orbiter sheet was photographically enlarged 2½ times to match the sample scale of 1:64,747. This enlargement was also accomplished on a stable base translucent material.

At the enlarged working scale, the size of both sample and source was 20" by 40". Employing the enlarged Orbiter Sheet as a guide, detail and lunar forms were added to a 20" by 20" portion of the sample. The remaining 20" by 20" portion was left untouched.

RENDERING PROCEDURE

The photographically enlarged Lunar Orbiter transparencies were positioned beneath the Film Graphics Range 4 Artwork.

The technique necessary to transfer the Orbiter information onto the Film Graphics sample required the utilization of tools capable of depicting minute detail. Special plasticized rendering tools were selected for this operation. All visible information was extracted from the Orbiter photographs and artistically transferred onto the original Range 4 copy. Consideration was given to the depths of crates and heights of rims so that the correct shadow relationship was maintained with the original Range 4 graphics.

With the addition of new lunar detail, a problem was encountered with regard to a contrast loss between the original background and some portions of the up-dating. It was found, however, that an automatic eraser was quite useful for discreetly varying the background and maintaining contrast levels to that indicated on the Orbiter Photograph.

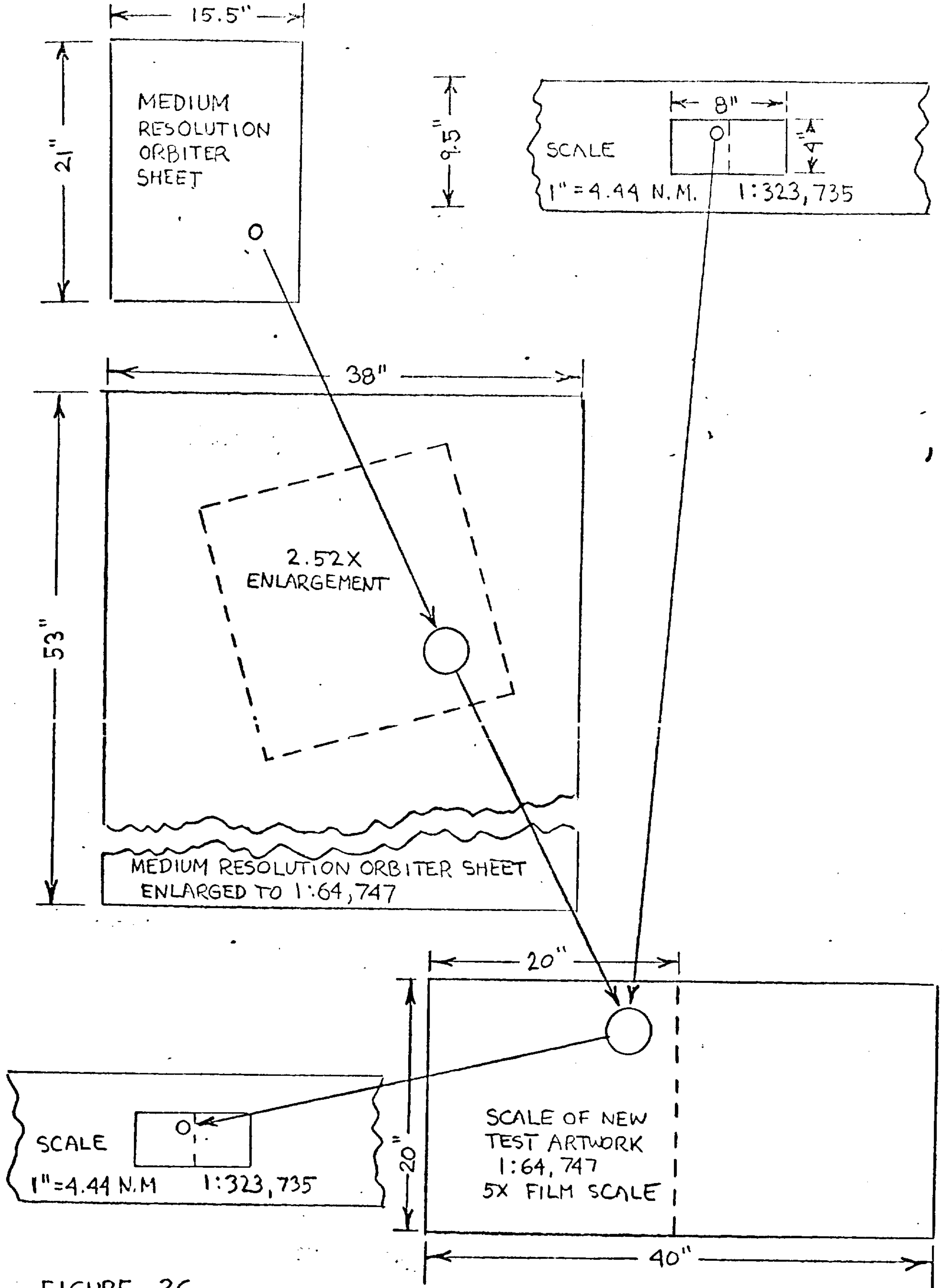
FINAL PHOTO PROCESSING

Upon completion of the rendering, both the enhanced and unenhanced portions of the sample were photographically reduced to a negative at a final scale of 1" = 4.44 N.M. The negative was then contact-printed to a positive on Kodak SO-226 Film (9½", with sprocket holes). The positive image was centered within ± .010" of the centerline of the film.

Two final positive samples were produced, one sample processed as black and white and one sample processed as magenta.

A flow chart of the procedure described is shown in Figure 26.

The techniques employed in the generation of the samples can be logically extended to the larger formats required for full scene updating. In this case, the original Film Graphics Artwork and Orbiter photographs would be enlarged to a common scale of 1:64,747. The Artwork would then be enhanced in sections. Each section would be reduced two (2) times to a negative at a scale of 1:129,494 which is the present artwork scale. Contact prints produced from these negatives would then be employed in the composition of a controlled mosaic lunar scene. Such a mosaic would be perfectly matched and uniform throughout. Upon completion, the mosaic would be photographically reduced 2¼ times to final scale in negative form. The negative would then be contacted printed to make the final positive which could be processed as either black and white or magenta.



15.5"
21"
MEDIUM
RESOLUTION
ORBITER
SHEET
9.5"
8"
4"
SCALE
1" = 4.44 N.M.
1:323,735
38"
53"
2.52X
ENLARGEMENT
MEDIUM RESOLUTION ORBITER SHEET
ENLARGED TO 1:64,747
20"
SCALE
1"=4.44 N.M
1:323,735
20"
SCALE OF NEW
TEST ARTWORK
1:64,747
5X FILM SCALE
40"

FIGURE 26

CONCLUSIONS AND RECOMMENDATIONS

From the preparation of the sample, useful information was learned regarding the minimum size and quantity of detail which can be practically generated in the artistic rendering of Orbiter type detail. An examination of the enhanced detail by projecting the completed magenta film strip onto a screen at forty (40) times enlargement indicated a very substantial increase in detail and a good similarity to medium range Orbiter photography.

This demonstrates the feasibility of artistically creating detail and of up-dating the Lunar Film Graphics.

A review of the hours required to prepare the sample and an extrapolation of those hours to the scope of the Artwork required for full Lunar Film Graphics up-dating indicates that a considerable cost would be involved. It is therefore in order to suggest a method whereby the detail of the sample can be achieved over a large area at only a small percentage of the straight extrapolated cost.

For a given scene, a sufficiently large area would be detail rendered, as in the sample, to provide Orbiter type micro-detail in the area of high interest (landing site). This information would then be photographically copied at a two-time reduction and a series of tone-matched prints would be prepared from the negative. Using a stable base material, one print would be cemented onto a grid so that its micro-detail would register with the micro-detail in the area of critical interest. Then the additional duplicate prints would be mosaicked in a random manner so that the entire scene area would be covered with micro-detail image.

To prepare an Orbiter detail enhanced scene, the original Artwork would be placed on the easel and exposed onto a negative. Then, the original Artwork would be removed and the mosaic of Orbiter type detail placed on the easel and double exposed in register to the first image.

Experiments would be made to determine the optimum balance of the two (2) exposures to obtain the most realistic Lunar image detail. This procedure would give detail fully equivalent to the sample over the complete scene at a substantially lower full-scene cost.

The elements of this process are given in Figure 27.

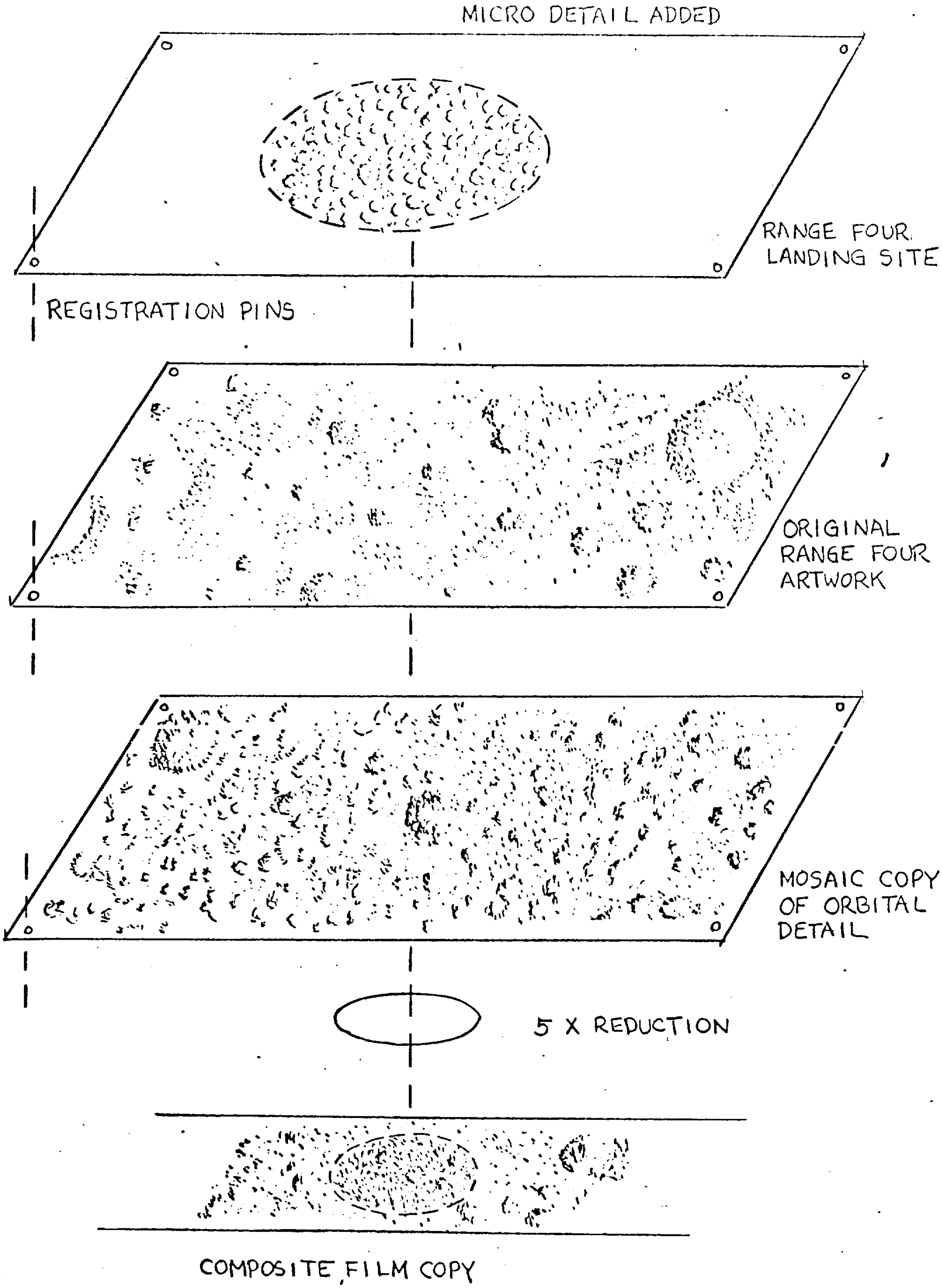

MICRO DETAIL ADDED
RANGE FOUR LANDING SITE
REGISTRATION PINS
ORIGINAL RANGE FOUR ARTWORK
MOSAIC COPY OF ORBITAL DETAIL
5 X REDUCTION
COMPOSITE FILM COPY

FIGURE 27

VARIABLE RANGE 3 FILM GRAPHICS FOR LMS AND LMPS
CCN - 12(S) Dated 2-25-69

Original Source Data

The AMS paper print mosaic of orbiter IV photography is at a scale of approximately 1:600,000. It covers the entire area specified for variable range 3 film graphics and has sufficient detail to use as source for the total area except the actual landing site area. In the landing site area the Lunar Mosaic, Scale 1:100,000, Site II P-8 was used for the full extent of its coverage.

Microdetail 1/50th of an inch or less on the final film was provided as hypothetical second generation detail.

Lunar photomaps scale 1:25,000 Site II P-8 and Factored Transparency Manuscripts, Corridor Area Site 3, Scale 1:100,000 and Landing Area site 3, Scale 1:10,000, were used as visual reference to insure a true portrayal of the lunar features.

Construction of Compilation Projection Grids

The projection for the variable scale lunar scene consists of three projections produced as a continuous lunar area centered about the equator. (Fig. 28)

The film scale on the LMS film from 22° East Longitude to 10° East Longitude is 3/4 inch per selenographic degree.

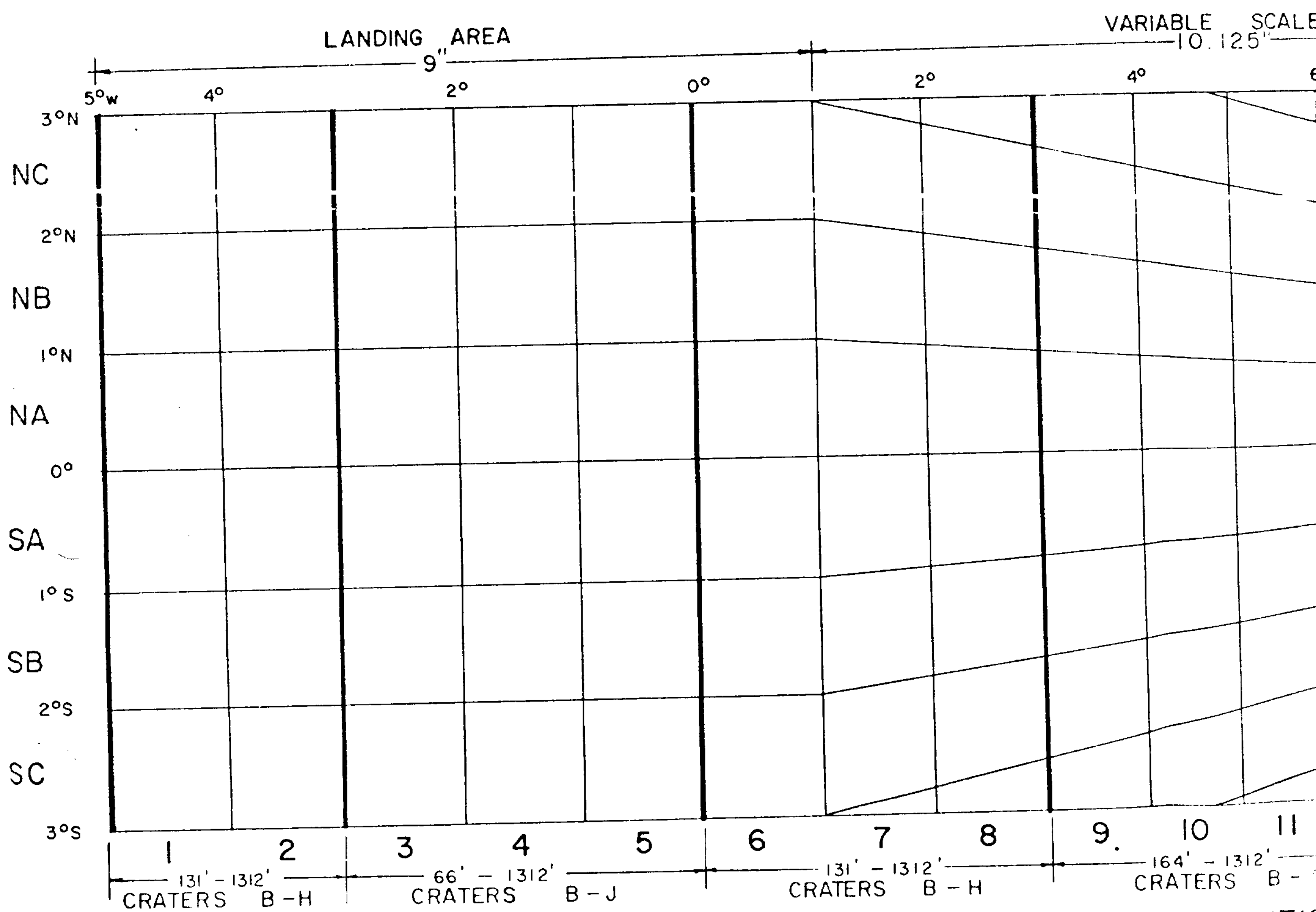
LMS

" = 12°	9" = 6°
° = 196.407 NM	6° = 98.204 NM
1" = 21.823 NM	1" = 10.912 NM
" = 1.333° (1° 20')	1" = .666° (0°40')
° = .75"	1° = 1.5"
1: 1,591,200	1: 795,600
1" = 132,600'	1" = 66,300'

COMP SCALE

318, 240	1: 159,120
" = 26,520'	1" = 13,260'

PROJECTION LAYOUT LMS FINAL FILM



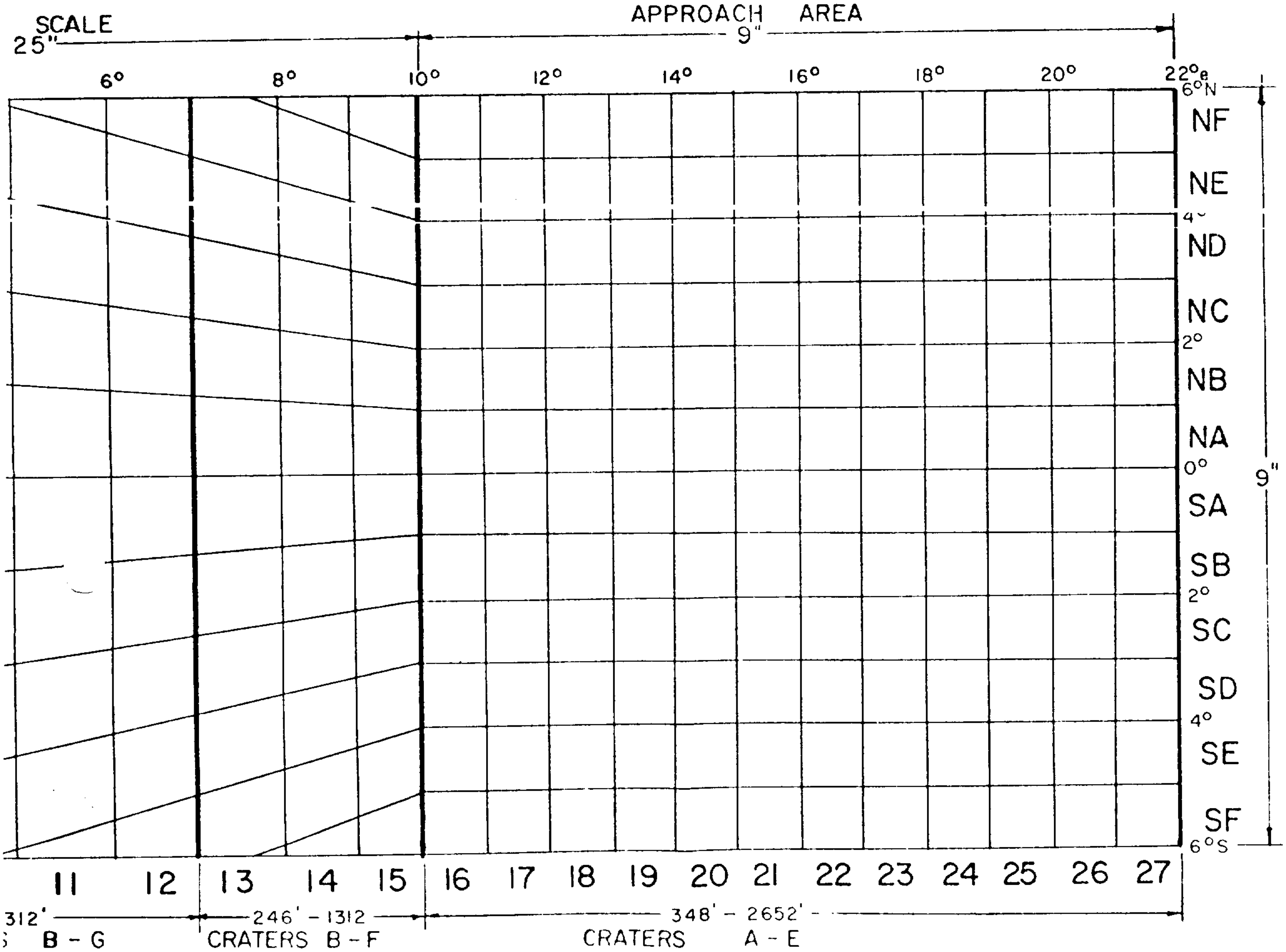
MINIMUM GROUND RESOLUTI
FOR VARIABLE SCALE

FIGURE 28

LMPS

1" = 14.548 NM	1" = 7.2743 NM
1" = .888°	1" = .444°
1° = 1.125"	1° = 2.25"
1: 1,060,800	1: 530,400
1" = 88,400	1" = 44,200

_ FILM SCALE



)LUTION REQUIREMENTS

ALE FILM

The film scale on the LMS film from 10° East Longitude to 1° East Longitude varies uniformly from 3/4 inch per selenographic degree to 1-1/2 inches per selenographic degree. The scale between longitude degrees is proportional to those formulated in the appendix to the addendum to Exhibit A dated January 21, 1969.

The film scale on the LMS film from 1° East Longitude to 5° West Longitude is 1-1/2 inches per selenographic degree.

The Compilation projection was constructed at 5 times the scale of the LMS final films, on cronaflex drafting film using a Haag Streit Coordinatograph.

Preparation of Base Panel for Artwork

The projection at compilation scale was transferred to a piece of 48 x 144 x 1/4 inch tempered masonite. This panel was reinforced with aluminum channels so that it would remain rigid and flat.

The selenographic projection was inked on the 1:600,000 AMS mosaic of orbiter IV photography in increments of 1°. Each 1° x 1° block was then assigned an identifying number using an Atlas grid system. The mosaic was then photographically copied at an intermediate scale. Using the compilation projection for control, each 1° x 1° segment of the orbiter IV mosaic negative was projected to scale using a Zeiss SEG IV rectifier.

The Zeiss SEG V rectifier in addition to projecting an image to the desired scale also has the unique capability of precise "X" any "Y" tilting of the image to transform the image to the desired geometry. This capability was required for projecting the images that fall in the variable scale area.

The scale adjusted and transformed photographs were then adhered to the masonite base using a combination of mosaicking and panelling techniques. They were accurately positioned by using the projections for control. (Fig. 29)

The entire photo assembly was then encapsulated under 4 coats of clear epoxy resin. With the surface wet sanded after each coat. Final result was a surface that showed all the photographic detail clearly and made a very receptive base for the paints. (Fig. 30)

<u>Rendering of Variable Range 3 Lunar Network</u>

Prior to the rendering operation for the lunar graphics, a suitable type paint had to be selected. The desired characteristics of the paint were: excellent adhesion to the encapsulated image, quick drying to assure ease of overpainting without delay, and portrayal of correct reflectivity for the photographic mask.

The paint finally selected as meeting these requirements was an acrylic polymer. This synthetic resin emulsion base paints can be thinned with water and dry quickly upon application.

Figure 29 - Rectified photographs being mosaicked to Range 3 Variable Scale Projection.

Figure 30 - Technician wet sanding photo assembly between spray coats of clear epoxy.

Utilizing pre-calculated shadow vectors the lunar detail existing on the orbitor photography was rendered in black, white, and shades of gray. In areas where height and depth information did not exist, good cartographic judgment was used in depicting the lengths of shadows. (Fig. 31).

A daily check was made with a Macbeth reflection densitometer on finished areas to assure that the correct reflectance values, necessary for the photographic reproduction were consistent.

During the total rendering task, scaled photographic overlays were used as the checking device. These overlays were made from the panelled orbitor image. Utilizing this procedure, a continuous check was made on the rendered lunar image throughout production.

Microdetail

Microdetail was provided as specified by Drawing #CFMSL 101768 "Minimum Ground Resolution for Variable Scale Film" and the bar chart in the appendix, "Number and Sizes of Craters per Unit Area."

The microdetail ranges from minimum size of 348' diameter in the approach area to 66' diameter in the landing site area.

The method used to provide this detail is as follows:

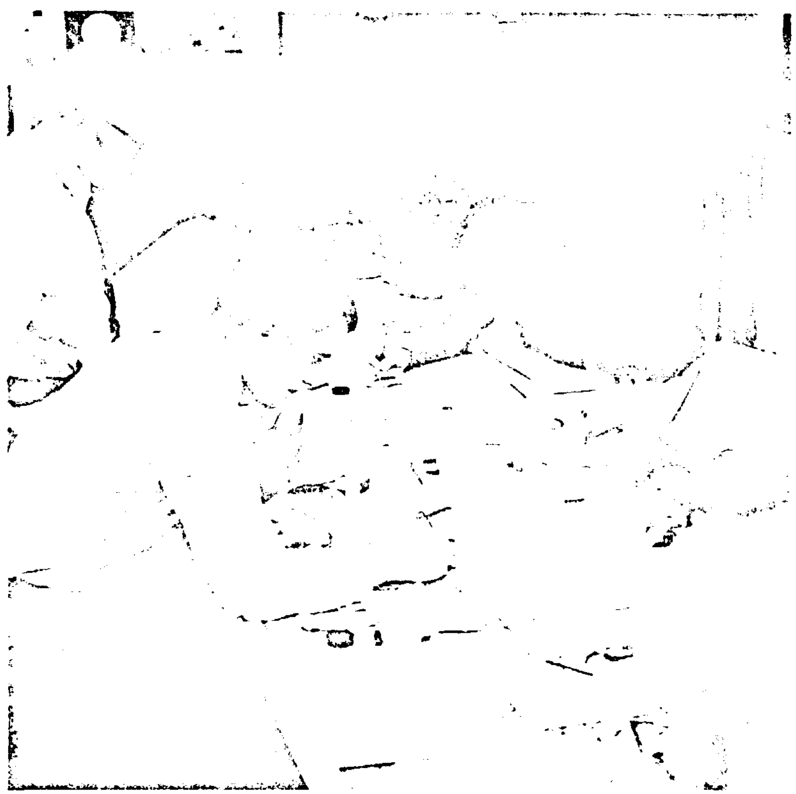


Figure 31 - Artists are rendering the lunar detail in black, white and shades of gray. Base image mosaic of orbiter photography.

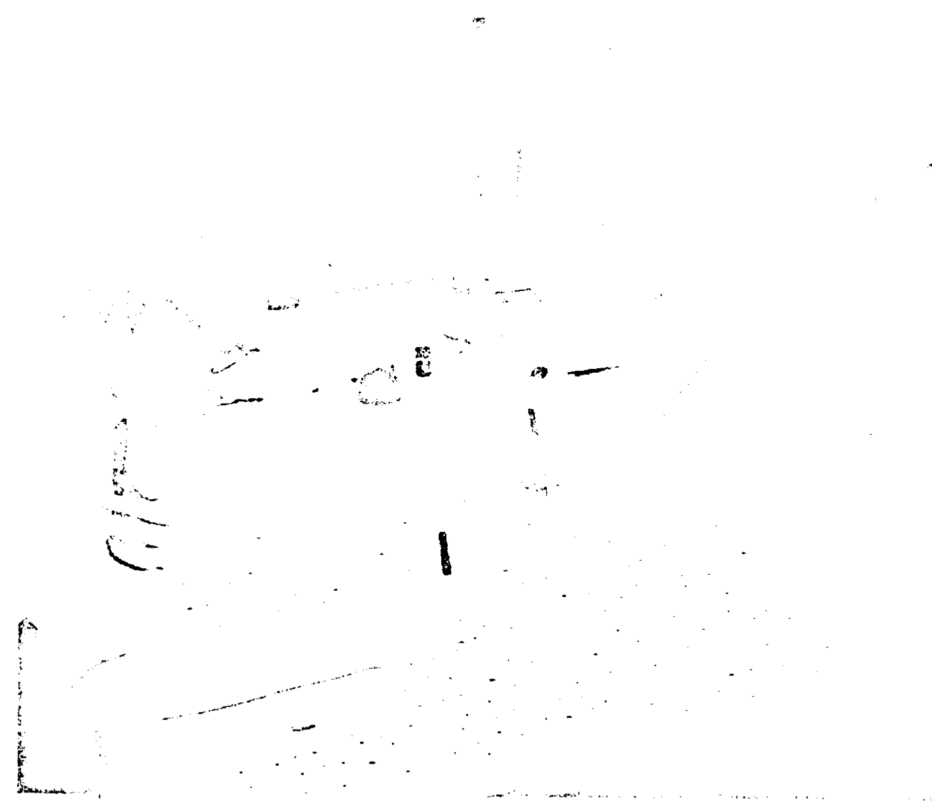


Figure 32 - Artists working on microdetail manuscript, adding craters in accordance with statistical distribution graph.

Within a 40 inch by 40 inch area of a piece of Conopaque film, craters were rendered that ranged from 348 feet to 2,652 feet in diameter and in numbers per unit area as specified, Fig. 32.

The 40 inch by 40 inch square was then reduced 8 times to be mosaicked on a 48 inch by 144 inch by 1/4 inch tempered masonite board which was reinforced with aluminum channels to assure rigidity and flatness, Fig. 33.

The microdetail mosaic board is 5 times larger than the final LMS film scale. The 40 inch by 40 inch square, then is therefore reduced a total of 40 times to cover approximately 1 square inch on the final film. In this manner, the microdetail does not cycle more than once per inch on the final film.

After the 40 inch section was copied, the artwork was returned and the required number of craters ranging from 246 feet to 348 feet were added within the 35 inch by 35 inch central portion of the original. The artwork was again copied this time at a 7 times reduction, and this combined with the 5 time reduction of the microdetail mosaic board will result in a 35 time reduction and still retains the minimum 1 inch cycle.

Because of the variable projection scale the craters maintain their relative scale size. The same procedure was repeated a total of 5 times adding smaller craters in the required quantities until a final saturation of craters down to 66 feet in size were added for the landing site area.

Figure 33 - The microdetail reduction photographs being mosaicked to master micro-detail panel.

Figure 34 - Copy camera easel with 20 inch x 20 inch test section of the variable scale master artwork.

The microdetail mosaic was copied at the precise reduction and orientation as the lunar artwork board. The microdetail was printed on an intermediate positive using a double exposure photographic technique.

Test Strips

Priority was given to rendering and mosaicking microdetail in a 20 inch by 20 inch area of the variable scale section of the total area. The two boards were then copied and the sensitometry worked out to provide 6 test strips as required. (Fig. 34) Three test strips were required each for the LMS and LMPS. All 6 were provided at the LMS scale to facilitate production of the complete films by minimizing the time the artwork would be unavailable to the artists.

Artwork and Camera Alignment

The lunar artwork was produced at 5 times the scale of the LMS final films. The LMPS films required a 3.333 times reduction of the lunar artwork. The LMPS also covers less distance in the latitudinal direction and is offset .562" north of 0° latitude on the final film.

The films for each simulator also required tick marks along the edge and the requirements were different for each system.

Because of these variations it was necessary to set up the artwork with the proper ticks and adjust the camera, easel, and lighting separately for each set of films. In this case the artwork and microdetail mosaic for LMS films were copied first. When the LMS films were copied the ticks required for the LMPS films were placed on the artwork. After the camera was aligned for LMPS scale the artwork and the microdetail mosaic were recopied.

Exposure

The same high quality equipment,optics and techniques were used to expose the variable range 3 films as were previously used for the original film graphics.

Film Imagery Layout for LMPS

Left and Right hand negative rolls were assembled using the negatives for the new variable range 3 and various negatives from the original film graphics as described earlier in this report. The new film positives are specified to be printed at a much higher gamma than the original films and in an entirely different orientation of images. This required making intermediate negatives from the original to accomplish the desired results.

Printing the Final Films

The master negatives were contact printed on Eastman Type 2420 film using Log-Etronic SP 10/70A Strip Printer. All required resolution charts, linearity charts and fiducial patterns were provided as specified.